(NASA-CR-180425) THE DEVELOPMENT PROCESS FOR THE SPACE SHUTTLE PRIMARY AVIONICS SOFTWARE SYSTEM (IBM Federal Systems Div.) 87 p Avail: NTIS HC A05/MF A01 CSCL 01D

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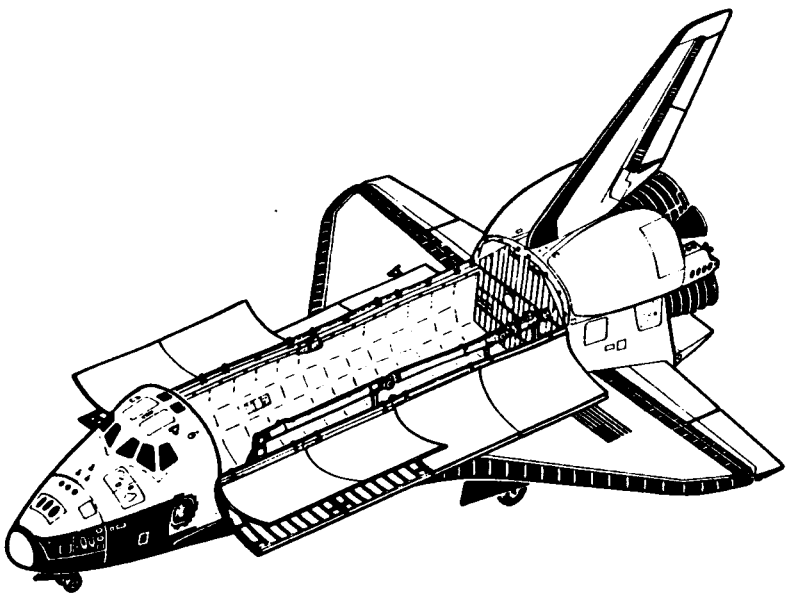

THE DEVELOPMENT PROCESS FOR THE SPACE SHUTTLE PRIMARY AVIONICS SOFTWARE SYSTEM

SPACE SHUTTLE PROGRAMS

IBM
Federal Systems Division
3700 Bay Area Boulevard
Houston, Texas 77058/1199

PRESENTATION TO COMMON CONFERENCE
OCTOBER 20, 1987
CHICAGO, ILLINOIS

T. W. KELLER
MANAGER, OBS PROJECT COORDINATION & CONFIGURATION MANAGEMENT

SOFTWARE CRITICAL TO NASA SHUTTLE

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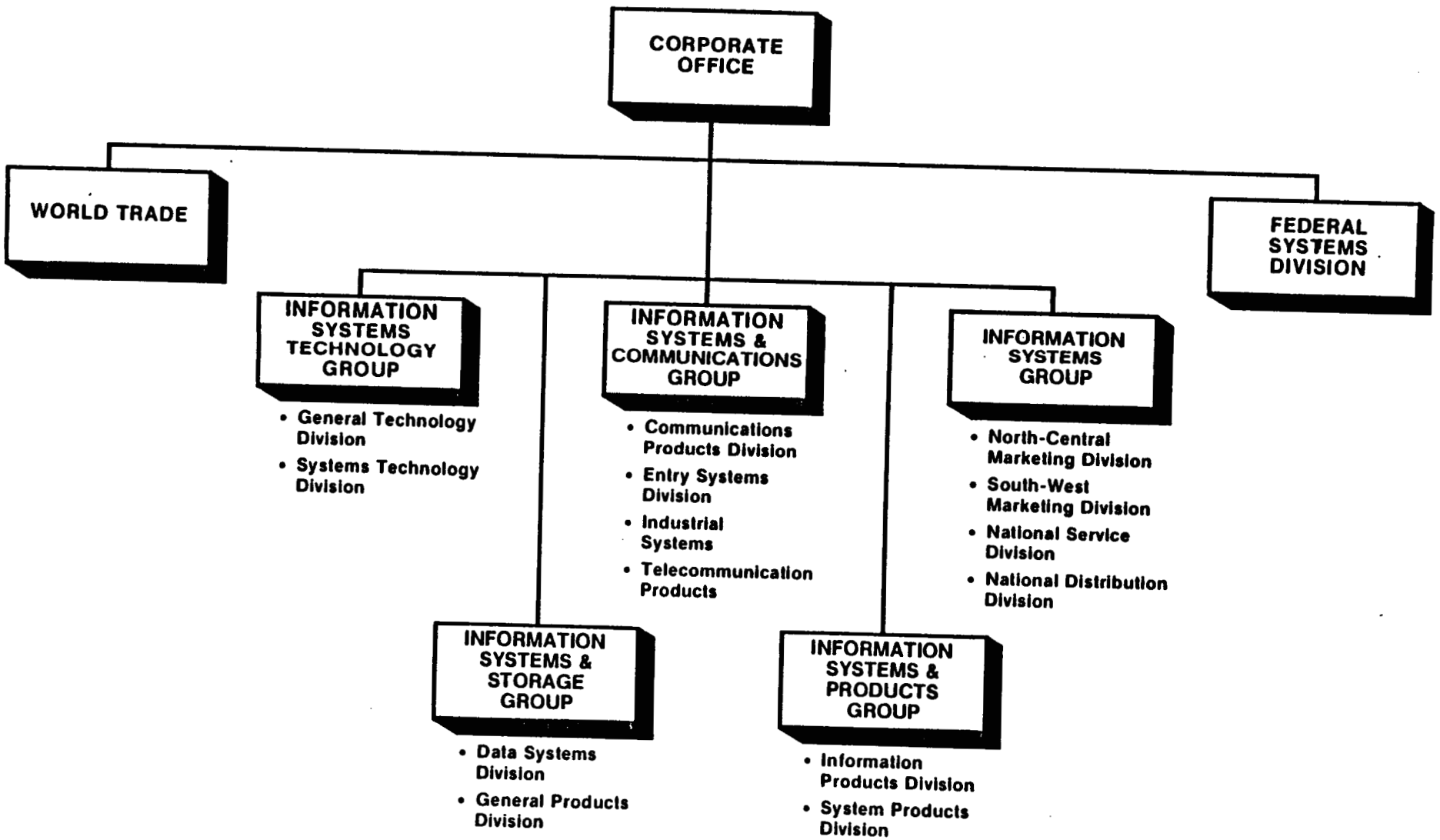
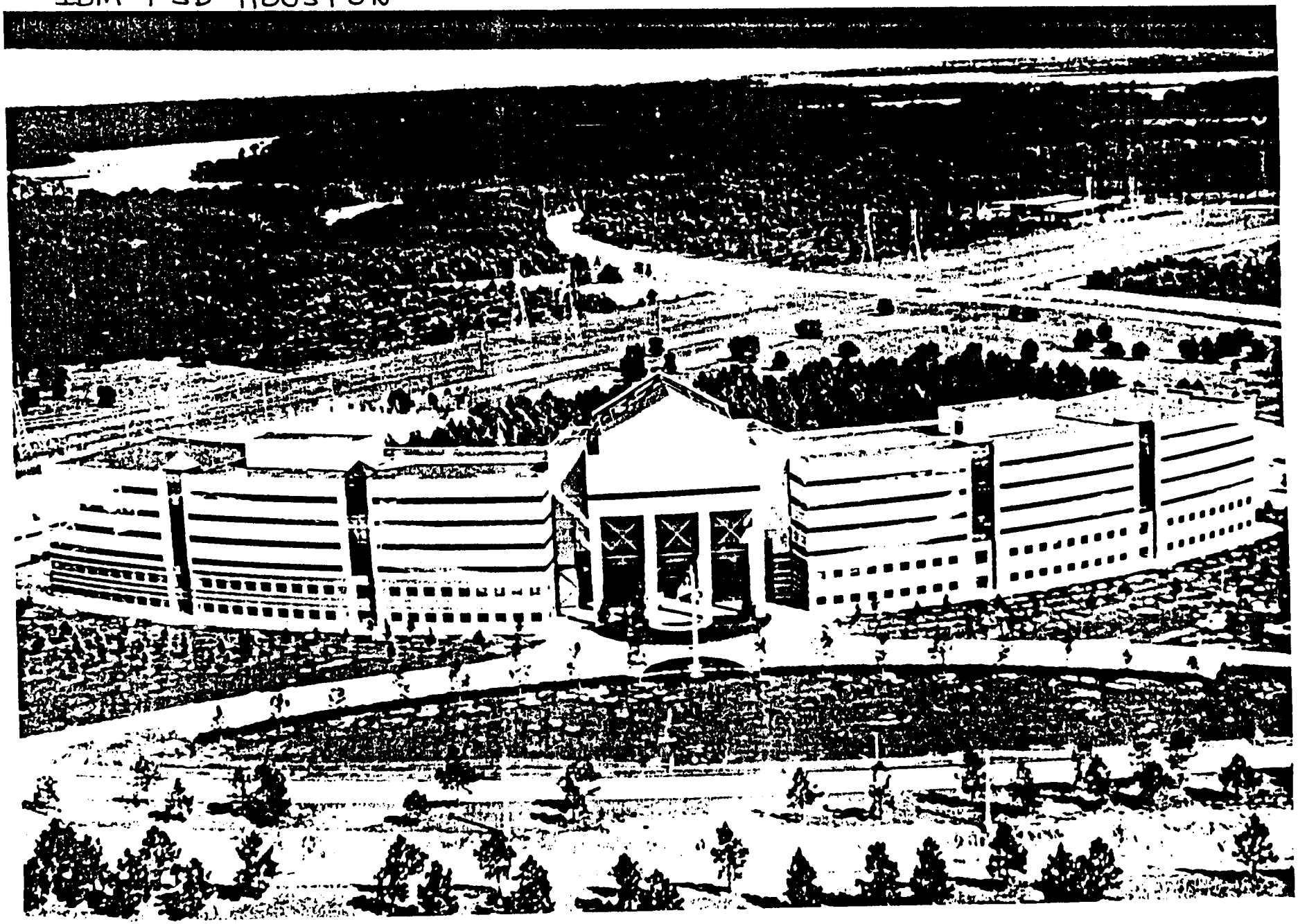
INTRODUCTION

IBM CORPORATE ORGANIZATION



IBM FSD HOUSTON



PROJECT OVERVIEW

SOFTWARE CRITICAL TO NASA SHUTTLE

PROJECT OVERVIEW

- Software Development Spanned Over 10 Years to the Base System Delivery in 1981
- Now Incorporating New Capabilities Into the Base System
- Current Level of 300 - 350 Software Developers Per Year
- Releases Tailored to Specific Missions by Data Reconfiguration
- All Work Done in the NASA Software Development and Production Facilities
- On-Line Access to Software Via Terminals

SOFTWARE CRITICAL TO NASA SHUTTLE

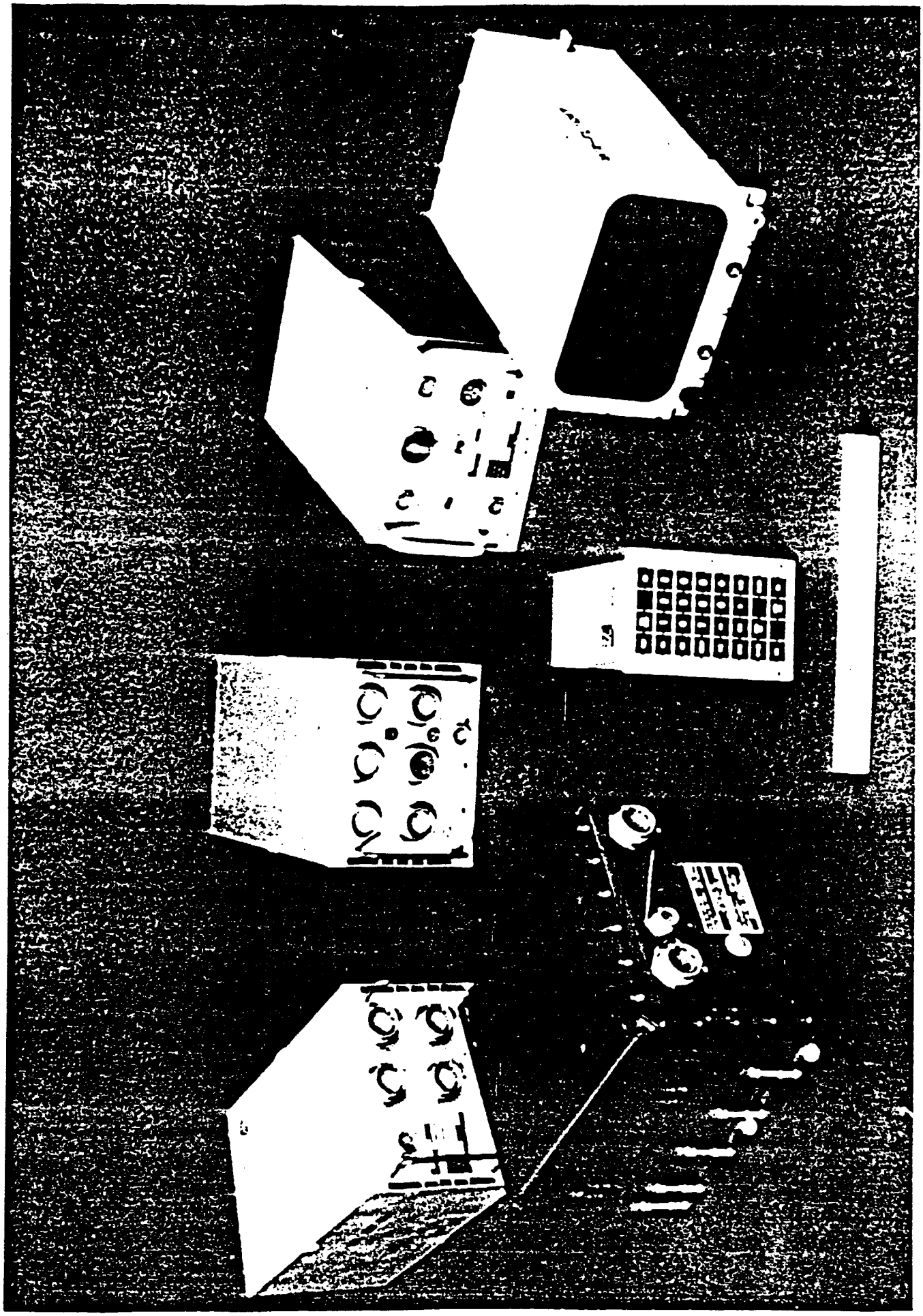
SOFTWARE DEVELOPMENT PHILOSOPHY

- Goals:
  - Meet Letter and Intent of Customer Requirements
  - Perform in Accordance with Customer Expectations
  - Error-Free Software
- Project Organization Functions
  - Requirements Analysis, System Architecture
  - Software Development (Design, Code, Test)
  - System Build and Integration
  - Independent Verification
  - Reconfiguration/Certification
  - Customer and Field Support
- Configuration Management
  - Formal Board Structure
  - Documents Requirements and Design Baselines
  - Stored in Configuration Management Data Base

IBM DEVELOPED SOFTWARE — SPACE TRANSPORTATION SYSTEM

SOFTWARE PROJECT	SOURCE LINES OF CODE (X 1000)	NASA CENTER
FLIGHT SOFTWARE SYSTEM	500K	JSC
SOFTWARE PRODUCTION FACILITY (SPF) (SIMULATOR AND SUPPORT SOFTWARE)	1,700K	JSC
MISSION AND PAYLOAD CONTROL CENTERS	4,000K	JSC
LAUNCH PROCESSING SYSTEM	2,500K	KSC
SPACELAB	800K	MSFC
TOTAL	9,500K	

PRIMARY AVIONICS SOFTWARE SYSTEM DESCRIPTION



SHUTTLE ONBOARD DATA PROCESSING SYSTEM

- **HARDWARE**
  - — 5 GENERAL PURPOSE FLIGHT COMPUTERS (GPC's)
    - WITH ASSOCIATED DISPLAYS, KEYBOARDS AND MASS STORAGE DEVICES

- **SOFTWARE**
  - — PRIMARY AVIONICS SOFTWARE SYSTEM (PASS)
    - SEPARATED INTO 7 OPERATIONAL PROGRAMS
    - KEYED TO SPECIFIC MISSION PHASES
  - — BACKUP FLIGHT SYSTEM (BFS)
    - PROVIDES ADDITIONAL REDUNDANCY DURING CRITICAL FLIGHT PHASES
    - EXECUTES ONLY DURING ASCENT AND ENTRY

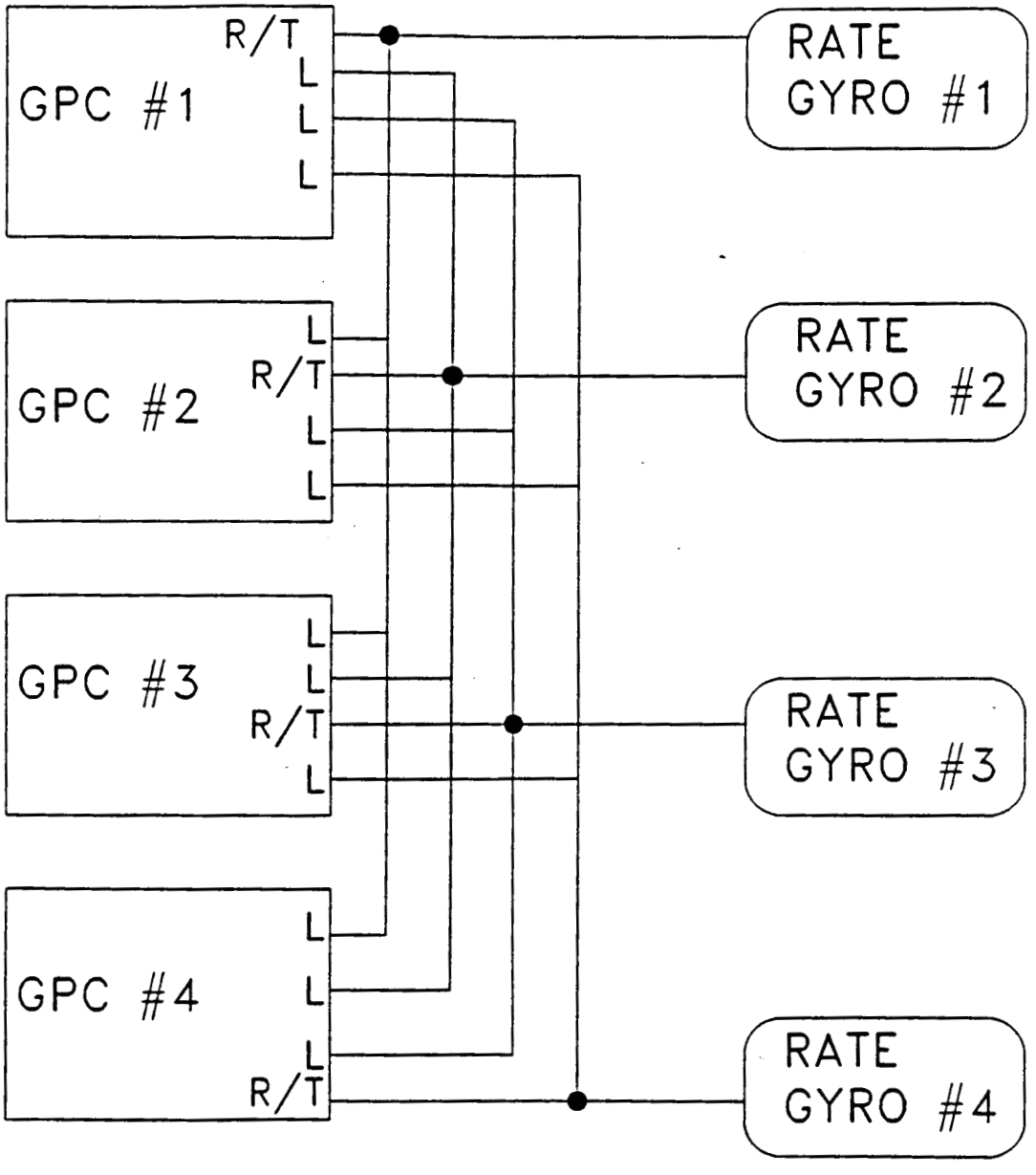
- **DURING CRITICAL MISSION PHASES (ASCENT, ENTRY, PRE-FLIGHT PREP.)**
  - — 4 OF 5 GPC's CONTAIN THE PRIMARY AVIONICS SOFTWARE EXECUTING REDUNDANTLY
  - — THE 5TH COMPUTER CONTAINS THE BACKUP FLIGHT SYSTEM EXECUTING IN PARALLEL (WITH OUTPUT COMMANDS INHIBITED)

- **IN LESS-CRITICAL MISSION PHASES (ON-ORBIT)**
  - — MULTIPLE PASS OPERATIONAL PROGRAMS EXECUTE IN 2 OR 3 GPC's
  - — REMAINING GPC's ARE POWERED-OFF

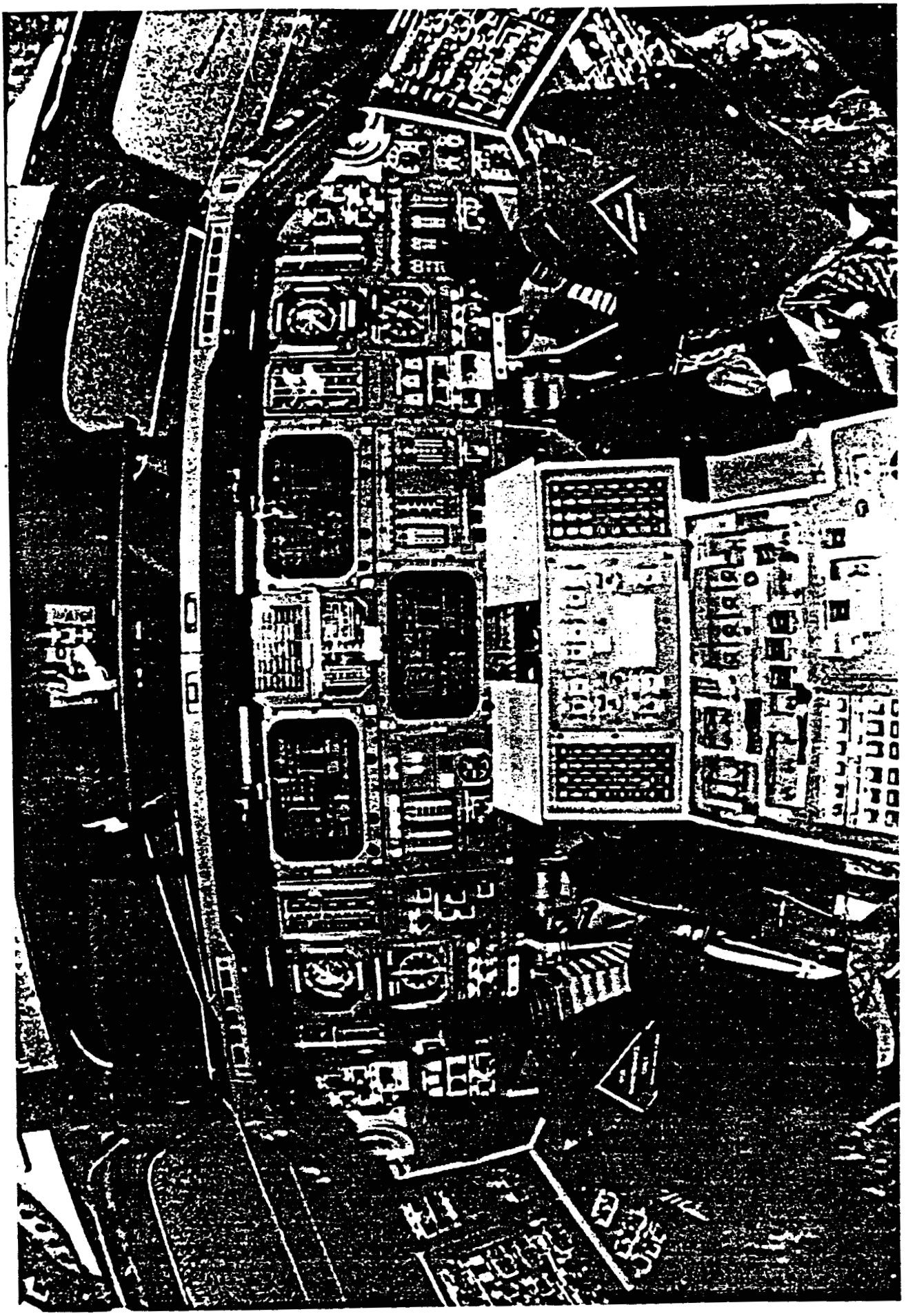
REDUNDANT GPC SETS

- Processes within GPCs synchronized.
- Identical input data required. Listen mode used to allow GPC to receive data from bus not under its control.
- Sync points inserted at appropriate locations in software.(~350/sec.).
- Dedicated sync lines interconnect all GPCs. All must send and receive synch discretes at sync window.
- Allows independent strings with simultaneous data access.

EXAMPLE OF REDUNDANT PROCESSING



LISTEN MODE



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PRIMARY AVIONICS SOFTWARE SYSTEM FUNCTIONS

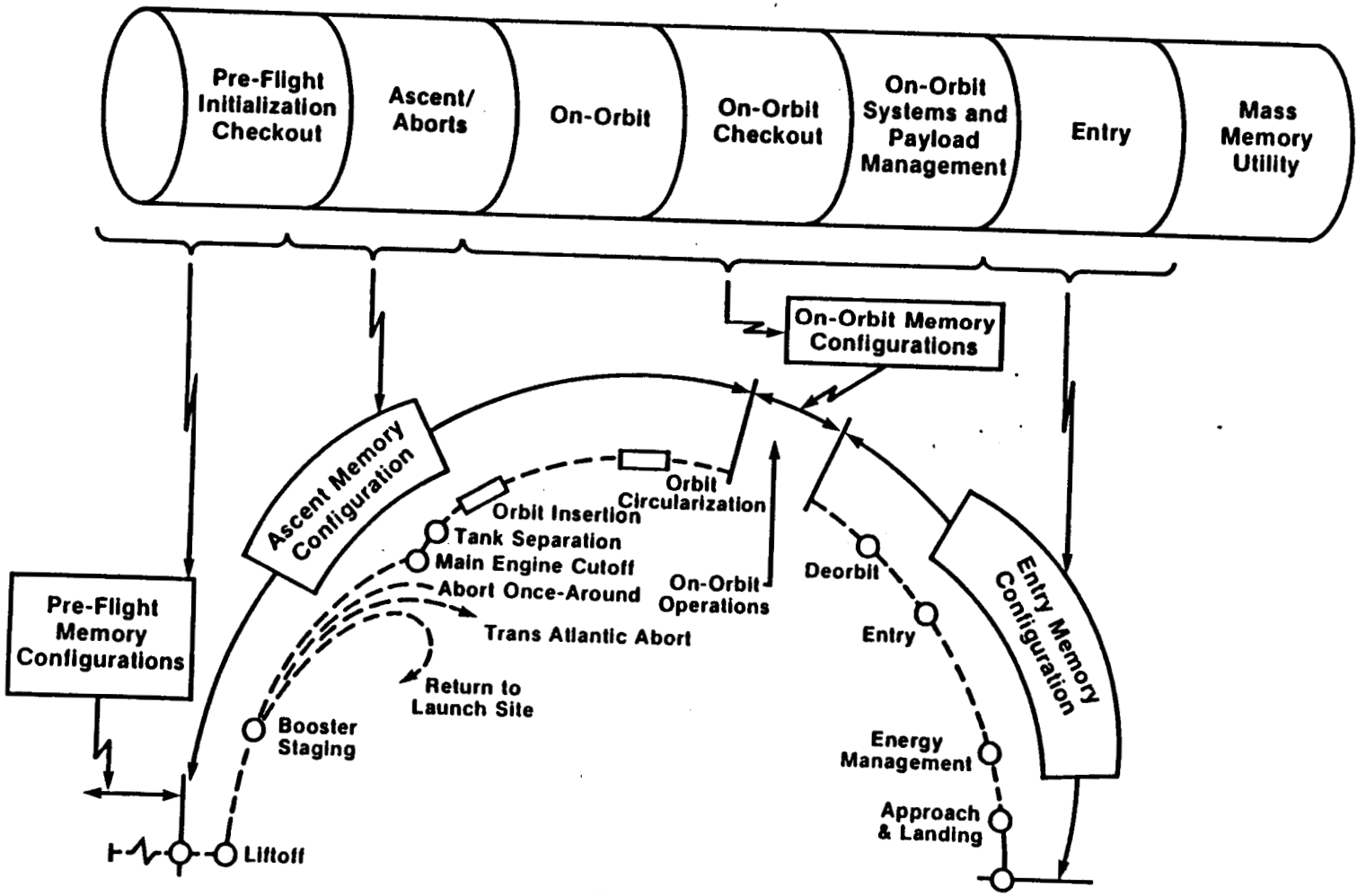
- **MISSION CRITICAL SOFTWARE SYSTEM**
- **SUPPORTS ALL FLIGHT PHASES FROM PRE-LAUNCH CHECKOUT THROUGH ROLLOUT**
  - — COMMANDS OR COMMUNICATES WITH HUNDREDS OF ONBOARD SYSTEMS
- **PREFLIGHT**
  - — VEHICLE SUBSYSTEMS CHECKOUT
  - — PAYLOAD CHECKOUT
  - — PROPELLANT LOADING
  - — TERMINAL COUNTDOWN SEQUENCING (E.G., ENGINE START)
- **ASCENT**
  - — AUTOMATIC AND MANUAL GUIDANCE, NAVIGATION AND FLIGHT CONTROL
  - — NOMINAL LAUNCH SEQUENCE (E.G., BOOSTER STAGING)
  - — ABORT SEQUENCING (E.G., RTLS, TAL, AOA, ATO)

PRIMARY AVIONICS SOFTWARE SYSTEM FUNCTIONS (continued)

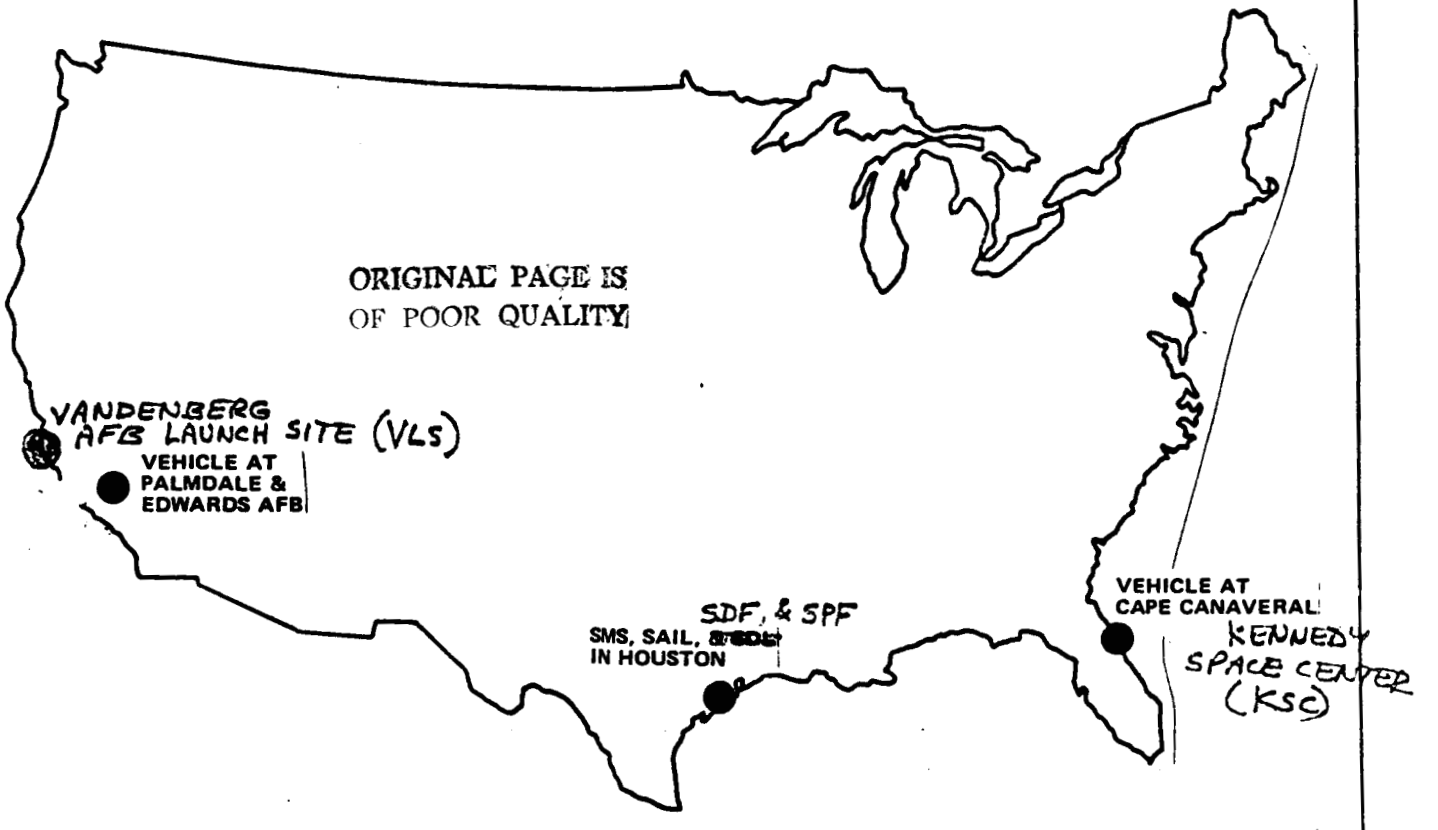
- **ORBIT**
  - — AUTOMATIC AND MANUAL GUIDANCE, NAVIGATION AND FLIGHT CONTROL
  - — VEHICLE SUBSYSTEM MONITORING/FAULT DETECTION/ANNUNCIATION
  - — PAYLOAD MONITORING, CONTROL, DEPLOYMENT
  - — REMOTE MANIPULATOR ARM CONTROL
  - — PAYLOAD BAY DOOR OPERATION
  - — COMMUNICATIONS ANTENNA MANAGEMENT
  - — ENTRY SYSTEMS CHECKOUT
- **ENTRY**
  - — COMPUTATIONS FOR DEORBIT ENGINE FIRING (TARGETING)
  - — AUTOMATIC AND MANUAL GUIDANCE, NAVIGATION AND FLIGHT CONTROL (THROUGH ROLLOUT AND BRAKING)

SOFTWARE CRITICAL TO NASA SHUTTLE

SOFTWARE CONFIGURATION FOR A TYPICAL SHUTTLE FLIGHT



Users Of On-board Shuttle Flight Software

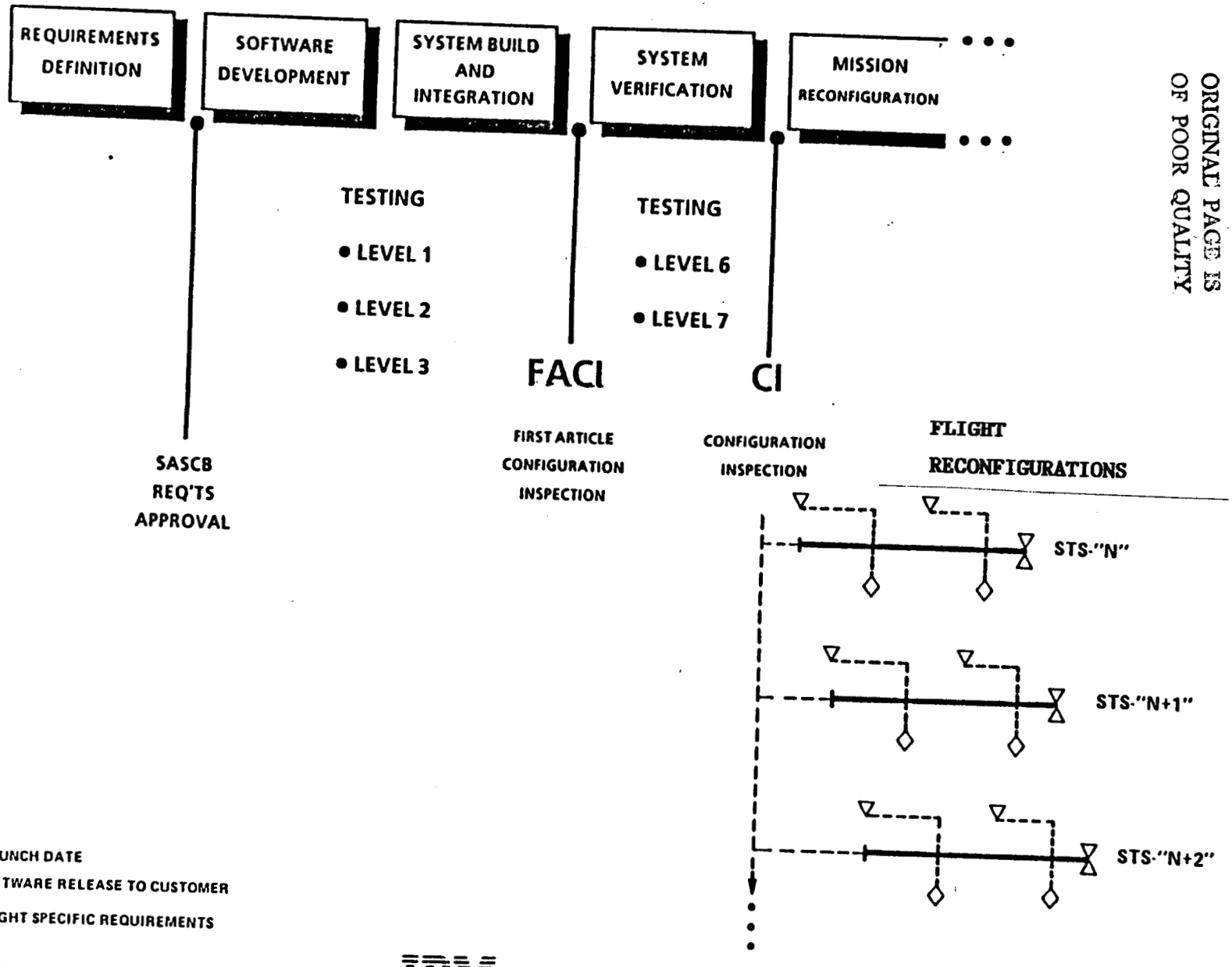


THERE ARE NINE PLACES WHERE ON-BOARD PRIMARY SOFTWARE DEVELOPED FOR THE SPACE SHUTTLE MAY BE IN USE:

- VEHICLE IN ORBIT
- VEHICLE AT CAPE CANAVERAL PREFLIGHT (KSC)
- VEHICLE AT EDWARDS AFB POSTFLIGHT
- SHUTTLE MISSION SIMULATOR (SMS)
- SHUTTLE AVIONICS INTEGRATION LABORATORY (SAIL)
- SOFTWARE DEVELOPMENT FACILITY (SDF)
- SOFTWARE PRODUCTION FACILITY (SPF)
- NEW ORBITER UNDER CONSTRUCTION AT PALMDALE
- VEHICLE AT VANDENBERG AFB PREFLIGHT (VLS)

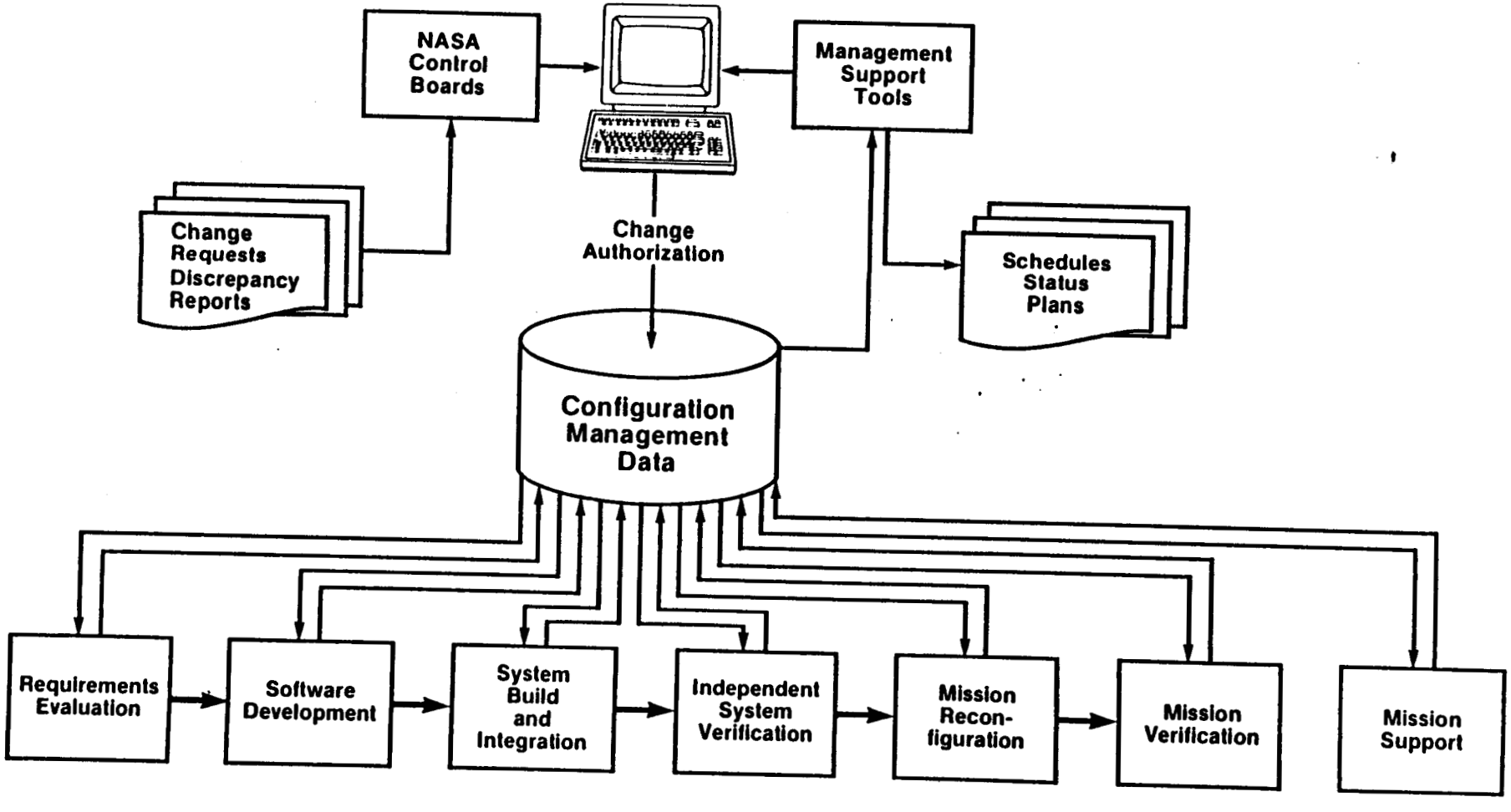
SOFTWARE DEVELOPMENT APPROACH

OPERATIONAL INCREMENT DEVELOPMENT MILESTONES



SOFTWARE CRITICAL TO NASA SHUTTLE

SOFTWARE DEVELOPMENT PROCESS

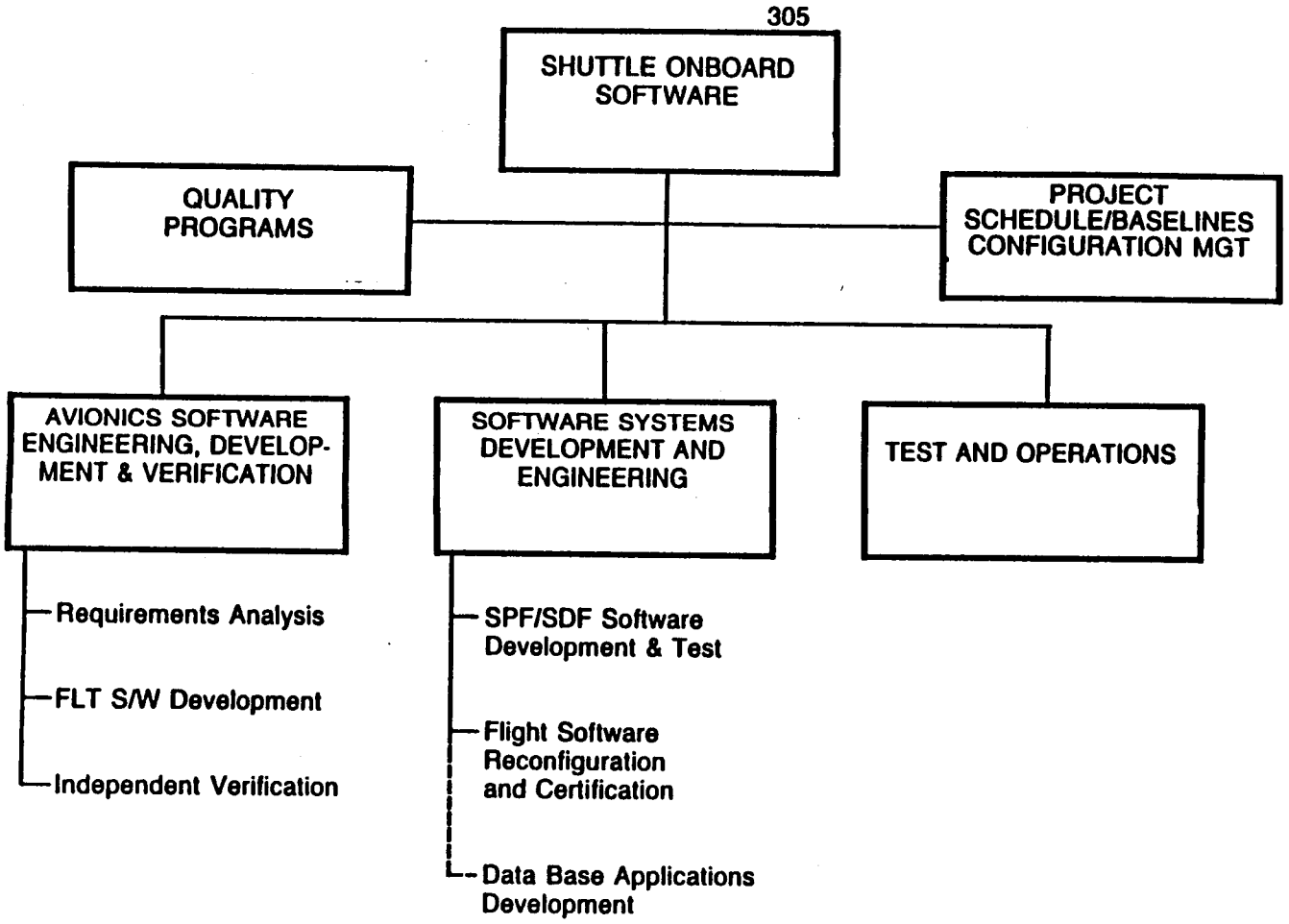


SOFTWARE DEVELOPMENT APPROACH

- **MAJOR DEPARTMENT AREAS**
  - — REQUIREMENTS ANALYSIS & SYSTEM ARCHITECTURE
  - — SOFTWARE DEVELOPMENT
  - — SYSTEM BUILD AND INTEGRATION
  - — INDEPENDENT VERIFICATION
  - — CUSTOMER AND FIELD SUPPORT
  - — RECONFIGURATION/CERTIFICATION

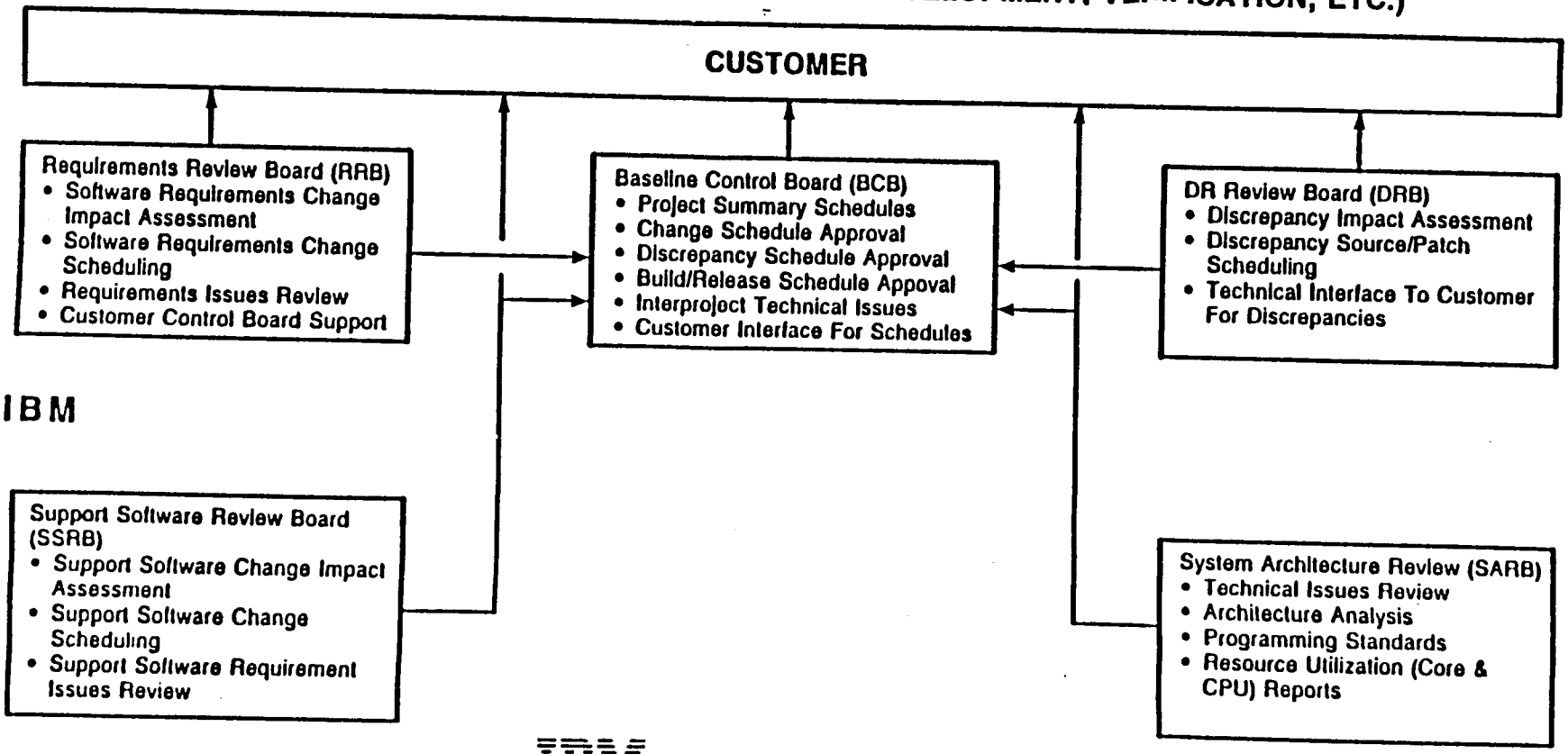
- **CONFIGURATION CONTROL (CONTROL BOARD STRUCTURE)**

SHUTTLE ONBOARD SOFTWARE ORGANIZATION



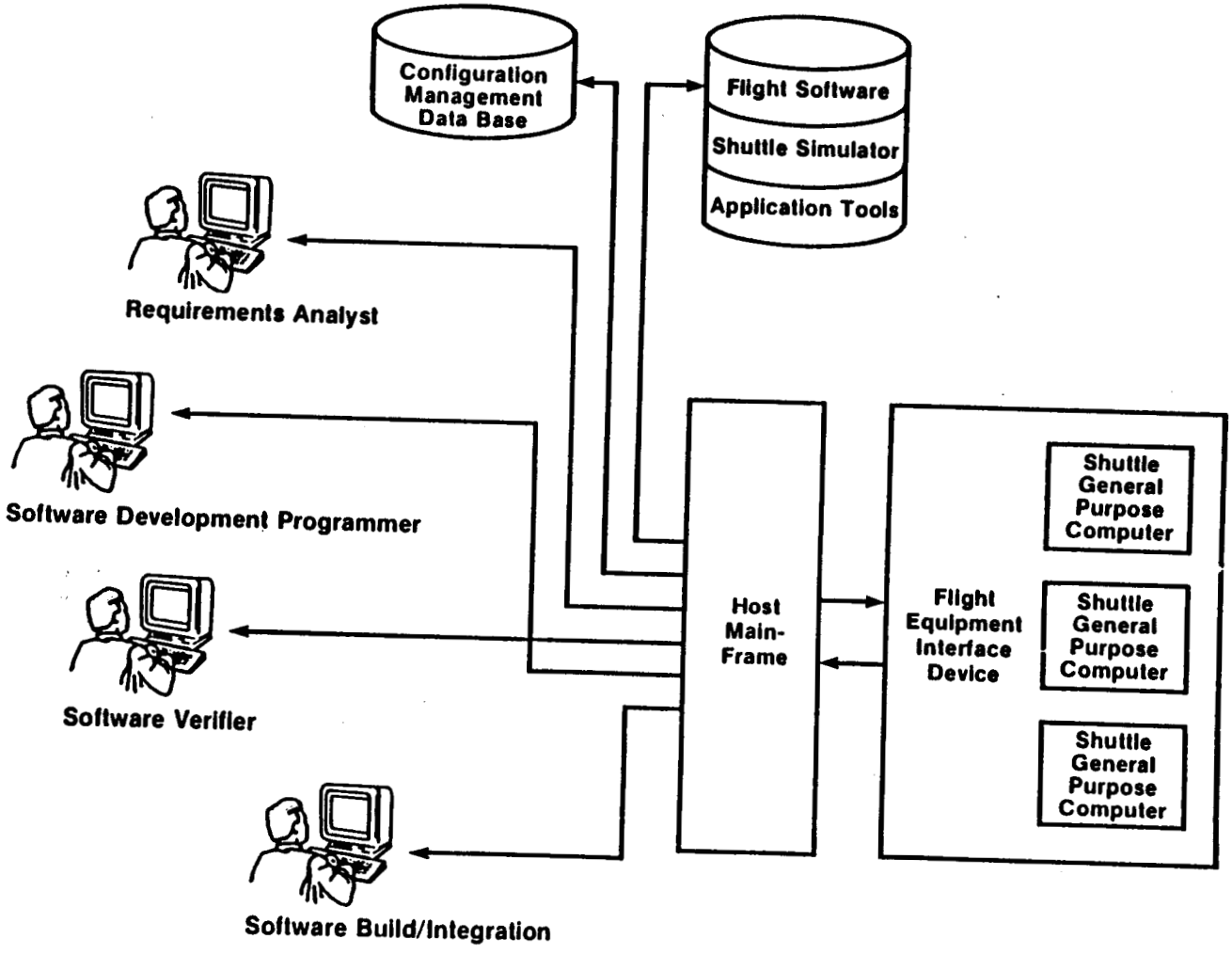
PROJECT CONTROL BOARD STRUCTURE

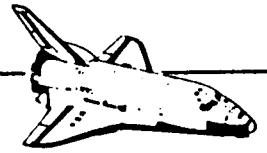
- PROJECT WIDE CONFIGURATION CONTROL MAINTAINED BY 5 CONTROL BOARDS
  - — PROJECT SCHEDULING AND OVERALL COORDINATION (BCB)
  - — SOFTWARE REQUIREMENTS (RRB)
  - — SOFTWARE DISCREPANCIES (DRB)
  - — PROGRAMMING STANDARDS AND SYSTEM ARCHITECTURE (SARB)
  - — SUPPORT SOFTWARE AND TEST BED (SSRB)
- CHAIRED BY KEY STAFF PERSONNEL
- REPRESENTATION BY ALL PROJECT AREAS (DEVELOPMENT, VERIFICATION, ETC.)



SOFTWARE CRITICAL TO NASA SHUTTLE

ONBOARD SHUTTLE SOFTWARE DEVELOPMENT





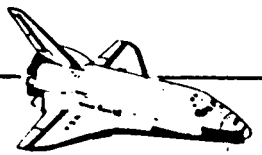
REQUIREMENTS ANALYSIS

- **DEDICATED REQUIREMENTS ANALYSIS GROUP FORMED TO INTERFACE WITH CUSTOMER AND DEVELOPMENT ORGANIZATION RESPONSIBILITIES INCLUDE:**
  - — ASSESSMENT OF CUSTOMER SUPPLIED REQUIREMENTS
  - — GENERATION OF SOFTWARE REQUIREMENTS

- **FUNCTIONS**
  - — REQUIREMENTS AND DESIGN TRADEOFFS
  - — ENSURE REQUIREMENTS MATURITY, COMPLETENESS, CLARITY
  - — HARDWARE/FIRMWARE/SOFTWARE COMPATIBILITY
  - — CPU AND MEMORY CONSTRAINT CONSIDERATIONS
  - — TESTABILITY OF REQUIREMENTS

- **TECHNIQUES AND TOOLS**
  - — CONCEPTUAL DESIGN TEAM CONCEPT TO ADDRESS EACH FUNCTIONAL AREA (CUSTOMER INVOLVEMENT)
  - — FORMAL REQUIREMENTS REVIEWS WITH SOFTWARE DEVELOPMENT, VERIFICATION AND FIELD SUPPORT PERSONNEL REPRESENTATION
    - MECHANISM FOR COMMUNICATION OF REQUIREMENT "LETTER" AND "INTENT"
  - — ANALYTICAL MODELING OF SOFTWARE SYSTEM

- **OTHER RESPONSIBILITIES**
  - — SYSTEM LEVEL (OPERATIONAL) TEST RESPONSIBILITY
  - — CONSULTATION TO ALL PROJECT AREAS (DEVELOPMENT, TEST, CUSTOMER, FIELD SUPPORT)
  - — CHANGE CONTROL BOARD MEMBERSHIP

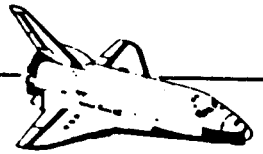


SOFTWARE DEVELOPMENT

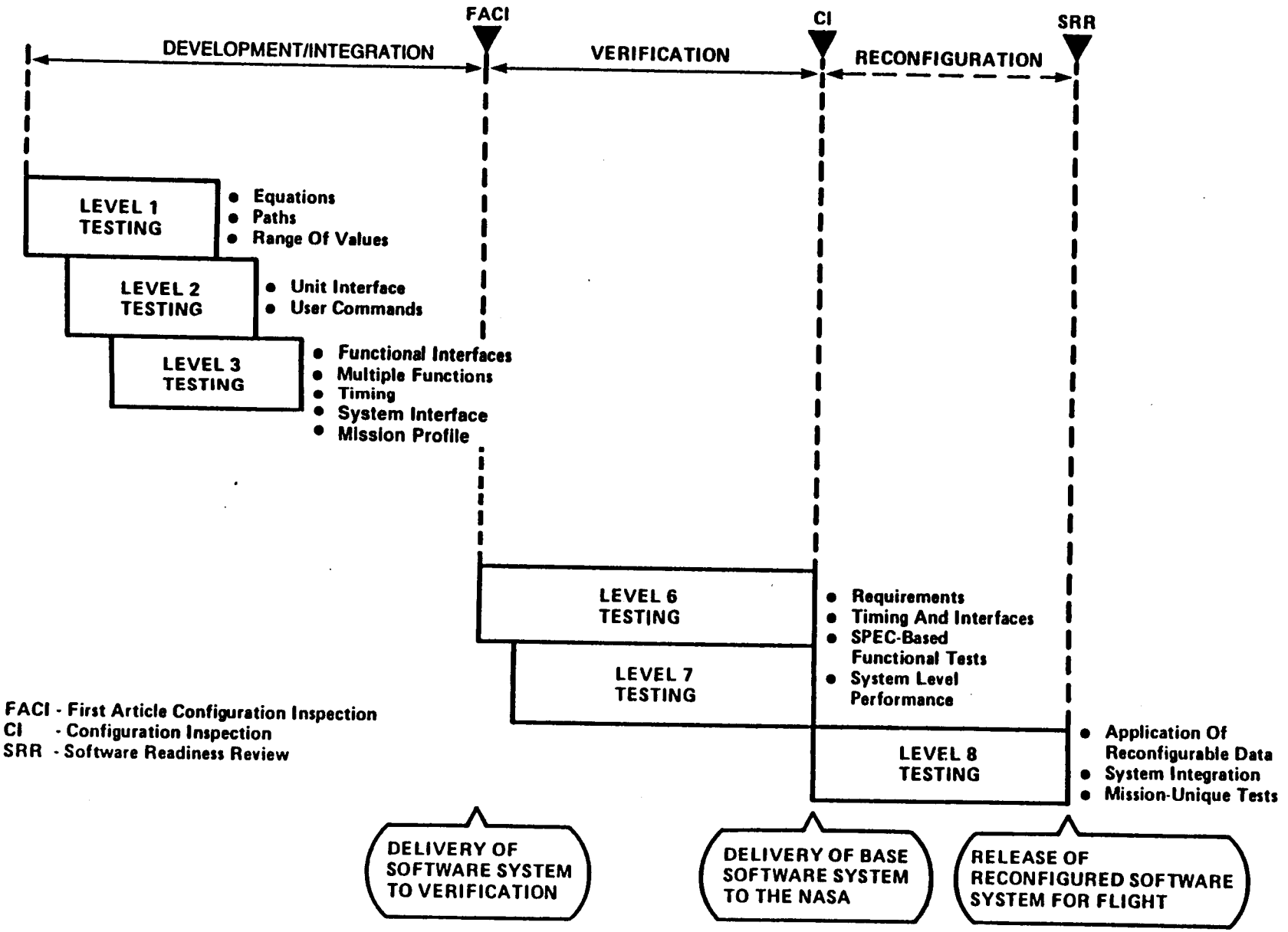
- **INDEPENDENT ORGANIZATION SEPARATE FROM REQUIREMENTS ANALYSIS, VERIFICATION, AND CUSTOMER SUPPORT GROUPS**

- **FUNCTIONS**
  - — PARTICIPATION IN INITIAL REQUIREMENTS BASELINE OR CHANGE ASSESSMENT AND SCHEDULING
  - — FUNCTIONAL AND DETAILED DESIGN
  - — CODE IMPLEMENTATION
  - — MODULE LEVEL UNIT TESTING (LEVEL 1)
  - — FUNCTIONAL LEVEL TESTING (MODULE TO MODULE INTERFACES, LEVEL 2)
  - — SUBMITTAL TO SYSTEM BUILD
  - — DESIGN DOCUMENTATION

- **TECHNIQUES AND TOOLS**
  - — FORMAL, HIGHLY STRUCTURED DESIGN AND CODE INSPECTIONS
    - • TRAINED MODERATORS AND PEER PARTICIPATION
    - • REPRESENTATIVES FROM REQ'TS ANALYSIS AND VERIFICATION
    - • CHECKLISTS WITH FORMAL SIGNOFF
    - • CODE AUDITING TOOLS
    - • ISSUES FORMALLY TRACKED AND DISPOSITIONED
  - — TESTING PERFORMED ON OPERATIONAL HARDWARE
  - — INTERIM MILESTONES TRACKED AT PROGRAMMER AND MODULE LEVEL AGAINST AUTOMATED DEVELOPMENT PLAN
    - • DESIGN START AND COMPLETE, CODE START AND COMPLETE, ETC.
  - — RESPONSIBLE FOR IMPLEMENTATION OF ALL DISCREPANCY CORRECTIONS
  - — FORMALIZED FEEDBACK AND ANALYSIS OF SOFTWARE DISCREPANCIES
    - • ANALYSIS OF INDIVIDUAL DISCREPANCIES TO IDENTIFY WEAKNESSES IN THE PROCESS
    - • TREND ANALYSIS



SHUTTLE AVIONICS SOFTWARE LEVELS OF TESTING

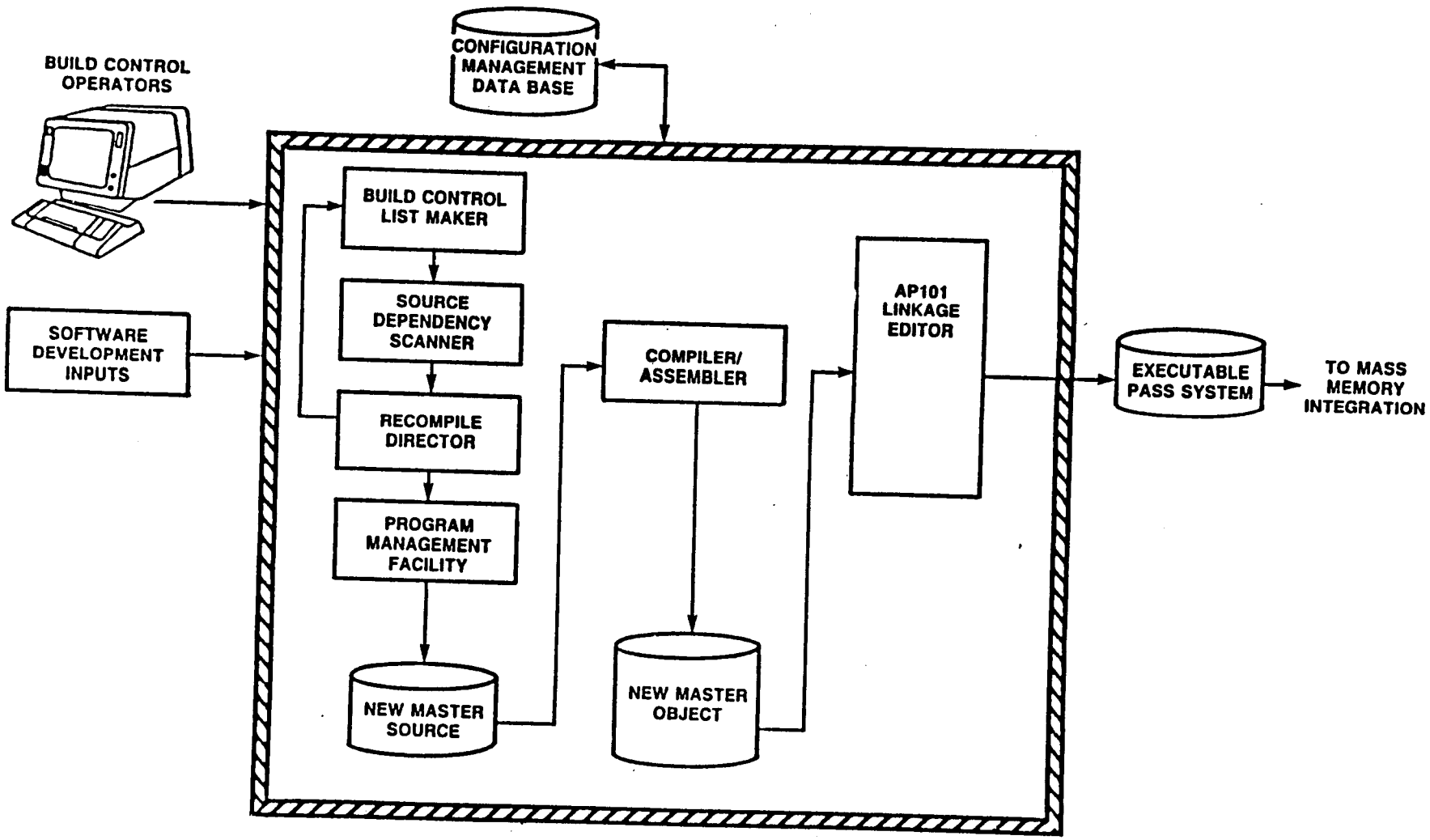


SYSTEM BUILD AND INTEGRATION

- **PRIMARY ELEMENTS**
  - — AUTOMATED SYSTEM BUILD
  - — MASS MEMORY INTEGRATION

PASS SYSTEM BUILD

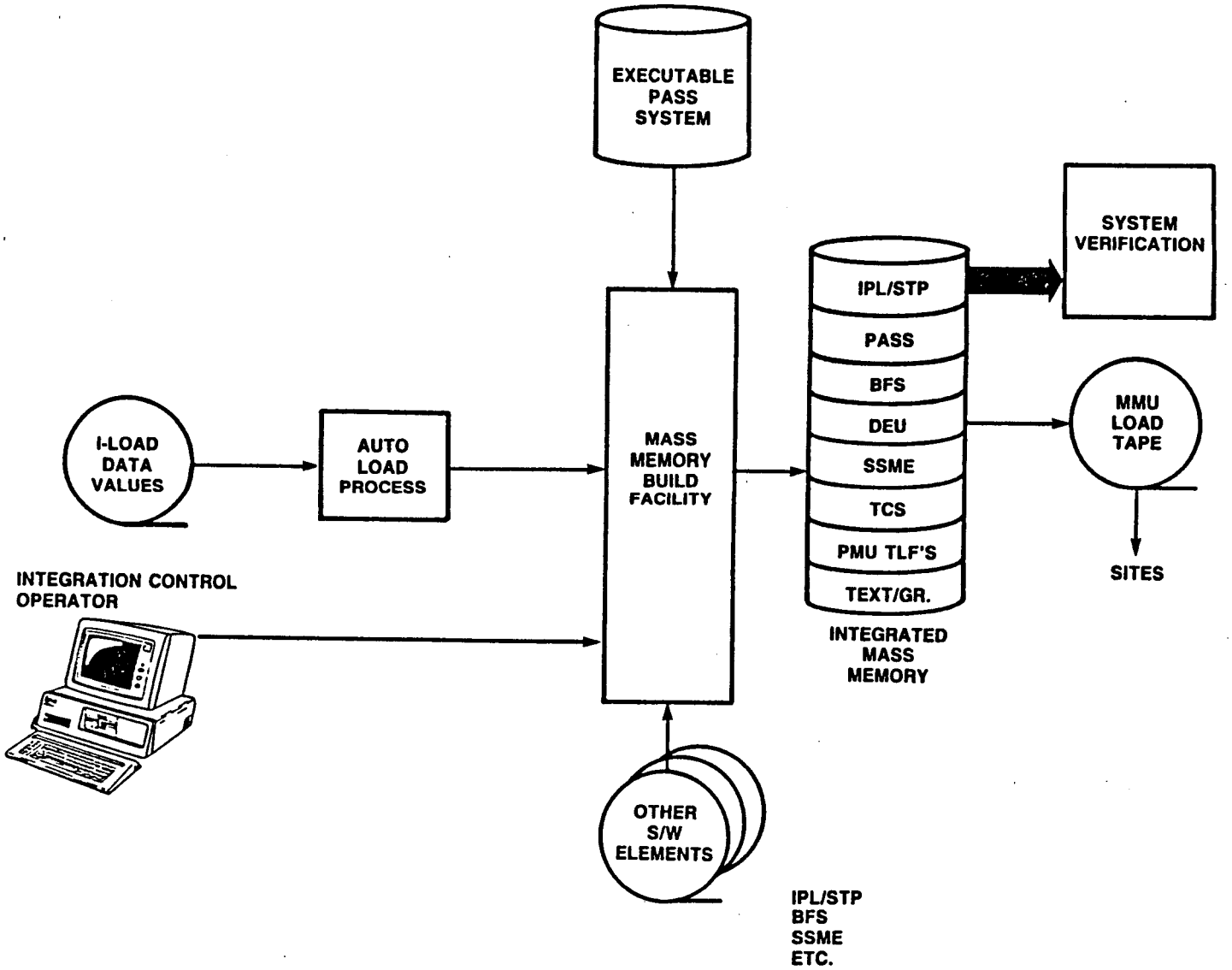
- ONLINE INTERACTIVE TRANSACTIONS (MENUS) PROVIDE AUTOMATED BUILD CONTROL
- UPDATED SOURCE MODULES AND NEW MODULES ARE PLACED INTO PERMANENT SYSTEM CONFIGURATION CONTROLLED DATA SETS
- A BUILD CONTROL LIST DRIVES THE SYSTEM BUILD PROCESS USING CONFIGURATION CONTROL INFORMATION FROM THE CONFIGURATION MANAGEMENT DATA BASE
- CONSISTENCY BETWEEN UPDATED SOURCE AND EXECUTABLE LOAD MODULES IS INSURED DURING COMPILATION AND LINK EDIT STEPS
- A SOURCE DEPENDENCY SCANNER AUTOMATICALLY IDENTIFIES OTHER SOURCE MODULES WHICH MUST BE RECOMPILED DUE TO DEPENDENCIES ON SOURCE BEING UPDATED
- A RECOMPILE DIRECTOR DETERMINES THE ORDER IN WHICH ALL SOURCE UPDATES MUST BE PERFORMED
- CHANGE ACCOUNTING INFORMATION (REVISION LEVEL) IS ADDED TO SOURCE LANGUAGE RECORDS AND IDENTIFICATION INFORMATION IS ADDED TO LOAD MODULES
- BUILD TERMINATION PROCESSING INDICATES STATUS OF ALL BUILT ITEMS IN THE CONFIGURATION MANAGEMENT DATA BASE
- NUMEROUS ANALYSIS REPORTS ARE OUTPUT FROM THE SYSTEM BUILD TOOLS, INCLUDING A LISTING TAPE OF ALL BUILT CHANGES



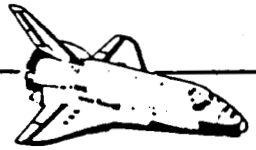
PASS SYSTEM BUILD

MASS MEMORY INTEGRATION

- AN AUTOMATED PANEL DRIVEN SYSTEM BY WHICH SOFTWARE ELEMENTS IN ADDITION TO PASS ARE INTEGRATED AND MAPPED INTO THE FORMAT REQUIRED BY THE MASS MEMORY UNITS
- I-LOAD DATA NEEDED TO ALLOW SUCCESSFUL SYSTEM EXECUTION IS APPLIED TO THE MASS MEMORY VIA THE AUTO-I-LOAD PROCESSOR AND THE MASS MEMORY PATCH UTILITY
- SOFTWARE ELEMENTS ARE INTEGRATED ON THE MASS MEMORY UNIT
  - PRIMARY AVIONICS SOFTWARE SUBSYSTEM (PASS)
  - INITIAL PROGRAM LOAD
  - BACKUP FLIGHT SOFTWARE (BFS)
  - SPACE SHUTTLE MAIN ENGINE
  - TFL/DFL
  - TEST CONTROL SEQUENCES
  - TEXT AND GRAPHICS
  - DEU
- PRINTED MASS MEMORY MAPS, PHASE TABLES AND OTHER REPORTS ARE GENERATED
- DELIVERY LOAD TAPES OR DATA SETS ARE CREATED FOR USE BY FACILITIES/VEHICLE



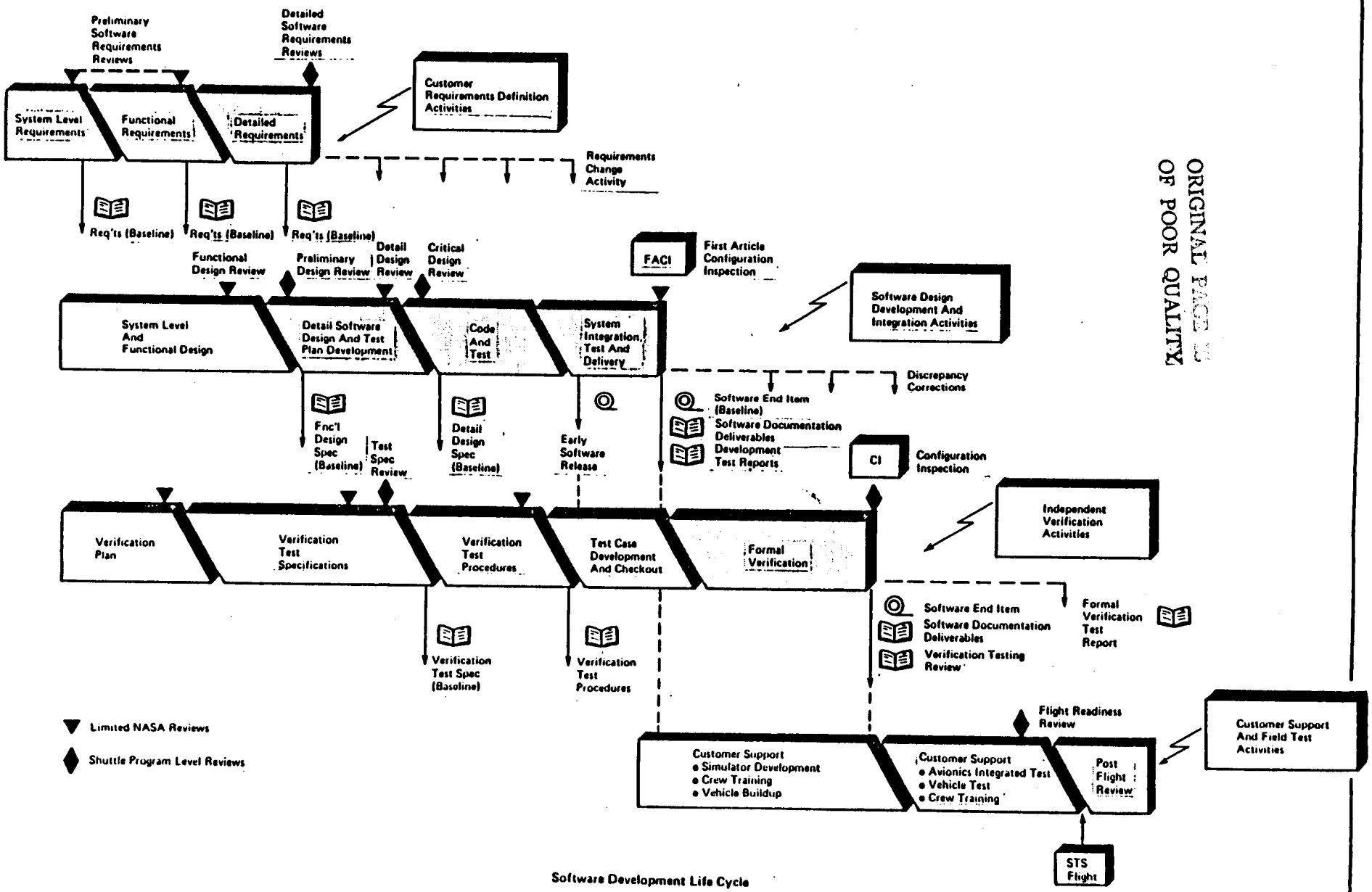
MASS MEMORY INTEGRATION



INDEPENDENT VERIFICATION

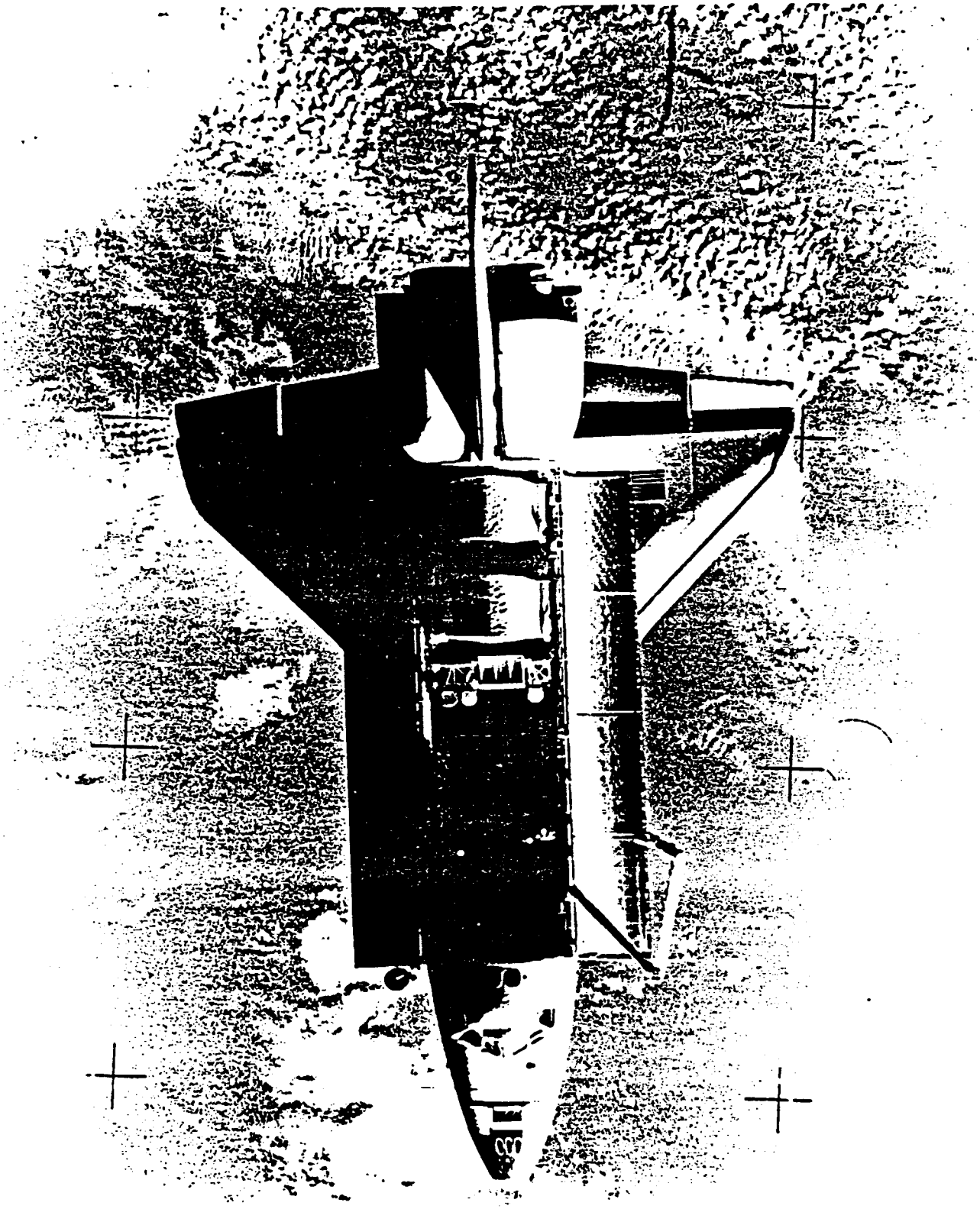
INDEPENDENT MULTI-LEVEL TEST PROGRAM

- USED ON SHUTTLE ONBOARD SOFTWARE PROJECT
- ASSUMES SOFTWARE IS "UNTESTED"
- ALL TESTING PERFORMED ON OPERATIONAL DPS FLIGHT HARDWARE IN SOFTWARE DEVELOPMENT FACILITY
- TWO LEVELS OF TESTING PERFORMED ON OPERATIONAL HARDWARE BY SEPARATE ORGANIZATIONS
  - DETAILED/FUNCTIONAL TESTING (MODULE/FUNCTIONAL TESTS AGAINST REQ'TS AND DESIGN), ALSO CALLED "SPECIFICATION BASED FUNCTIONAL TESTING"
  - SYSTEM LEVEL PERFORMANCE TESTING UNDER OPERATIONAL CONDITIONS
- TEST STANDARDS AND FORMAL TEST CASE REVIEWS TO ASSURE QUALITY
- STATIC CODE ANALYSIS TO AUGMENT TESTING
- RESPONSIBLE FOR REGRESSION TESTING OF ALL CHANGES
- FORMALIZED FEEDBACK AND ANALYSIS OF SOFTWARE DISCREPANCIES
  - ANALYSIS OF INDIVIDUAL DISCREPANCIES TO IDENTIFY WEAKNESSES IN THE PROCESS
  - TREND ANALYSIS
- INTERIM MILESTONES TRACKED AT THE TEST ANALYST, MODULE OR CHANGE LEVEL
  - COMPARISON TO AUTOMATED DEVELOPMENT PLAN
- DOCUMENTATION (TEST SPECIFICATIONS, PROCEDURES, SIMULATION CASES AND REPORTS)

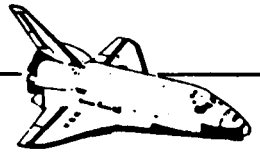


Software Development Life Cycle

IBM SPACE SHUTTLE PROGRAMS



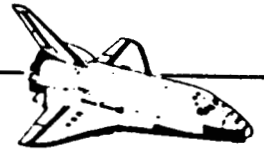
USER SUPPORT
AND
PROBLEM DIAGNOSIS



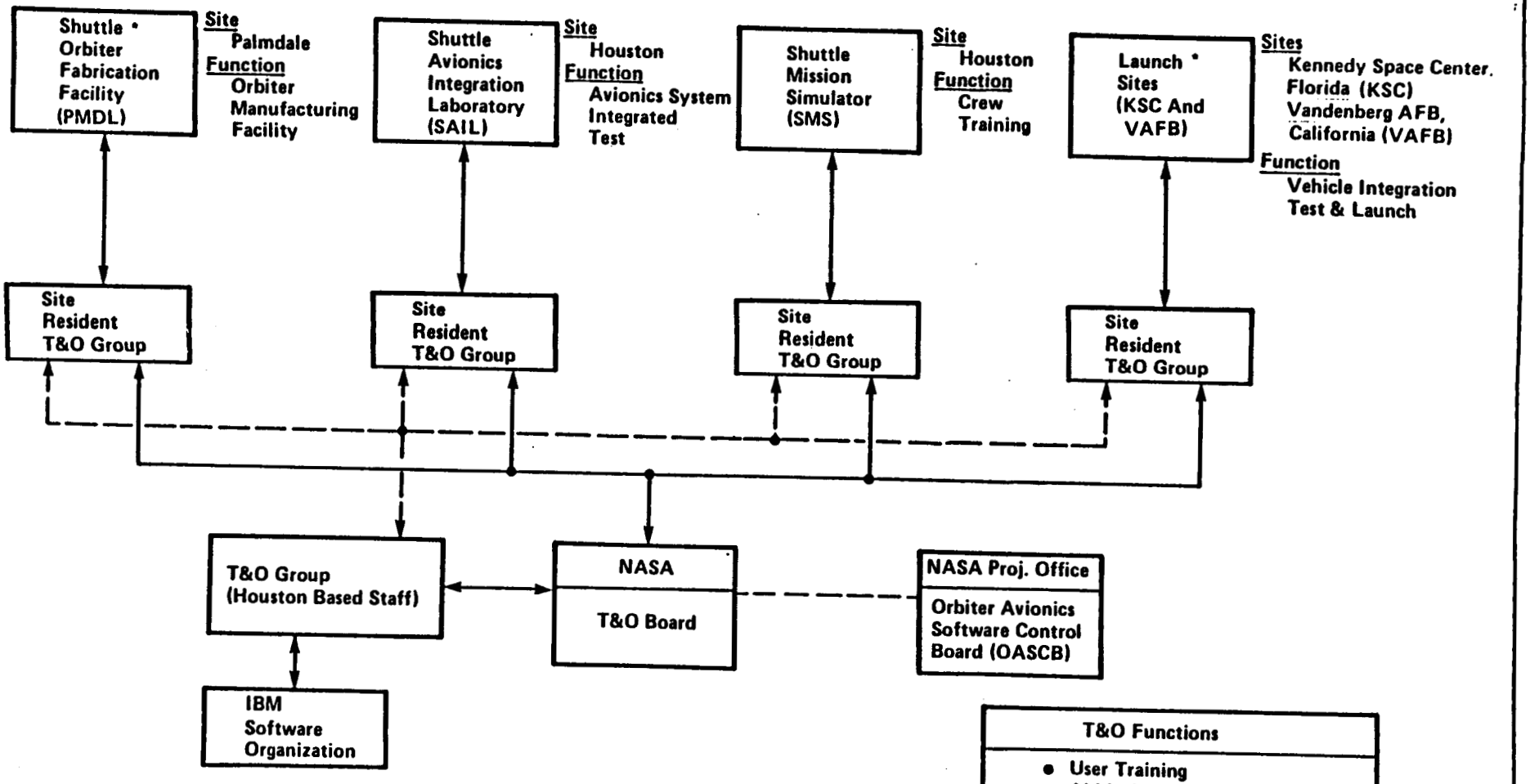
CUSTOMER SUPPORT AND FIELD OPERATIONS

FIELD SITE RESIDENT PERSONNEL WITH RESPONSIBILITIES AS FOLLOWS:

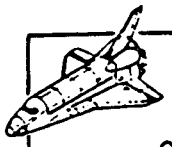
- SOFTWARE INSTALLATION AND MAINTENANCE
- USER TRAINING
- USER LIAISON
- CUSTOMER TEST SUPPORT
- OPERATIONS SUPPORT



TEST AND OPERATIONS ORGANIZATION INTERFACES

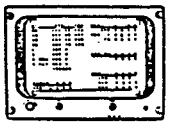


* No Palmdale or Vandenburg support to be provided in 1987.

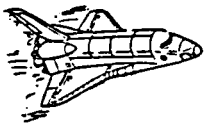


IBM PROBLEM DIAGNOSIS

SIMULATIONS
AND TRAINING

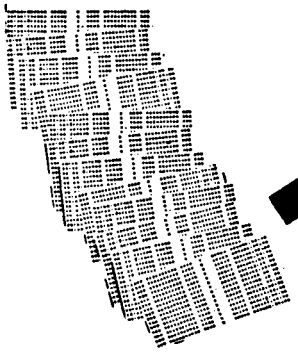


IN FLIGHT

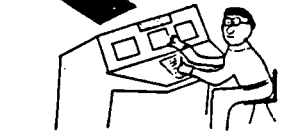


INITIAL CLUES

- DISPLAYS (PHOTOS)
- VERBAL DESCRIPTIONS
- VEHICLE DYNAMICS
- LOG OF KEYBOARD INPUTS
- MEMORY DUMPS
- TELEMETRY DOWNLIST
- CONSOLE LOGS
- TABULAR PARAMETRIC DATA



VERIFICATION
AND TESTING



GROUND SUPPORT

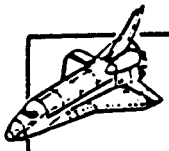
PROBLEM

IBM
FLIGHT
SOFTWARE
SUPPORT

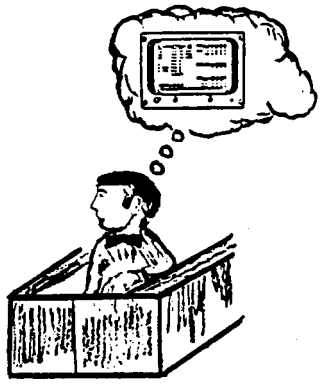
DIAGNOSIS

MATRIX OF
EXPERTISE

RESOLUTION



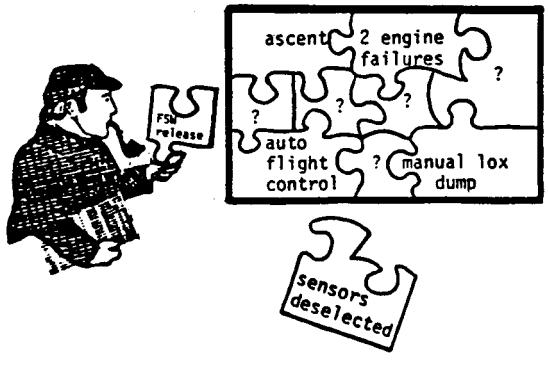
FACT FINDING



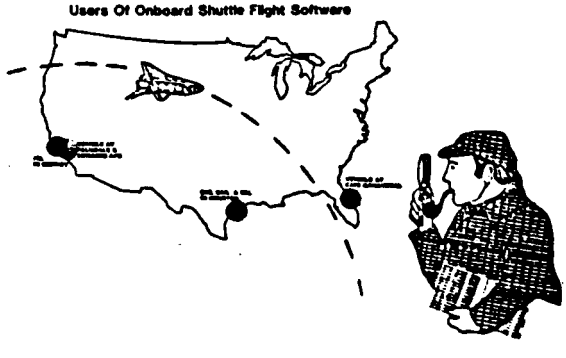
1. QUESTION THE WITNESS
   - WHAT DID HE OBSERVE

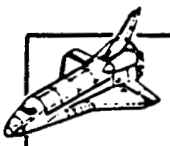
2. DETERMINE FLIGHT SCENARIO SURROUNDING PROBLEM

   MEMORY CONFIGURATION
   MANEUVERS EXECUTED
   KEYSTROKES ENTERED
   FAILURES EXPERIENCED
   .
   .
   .



3. SEARCH FOR USERS WITH SIMILAR SYMPTOMS



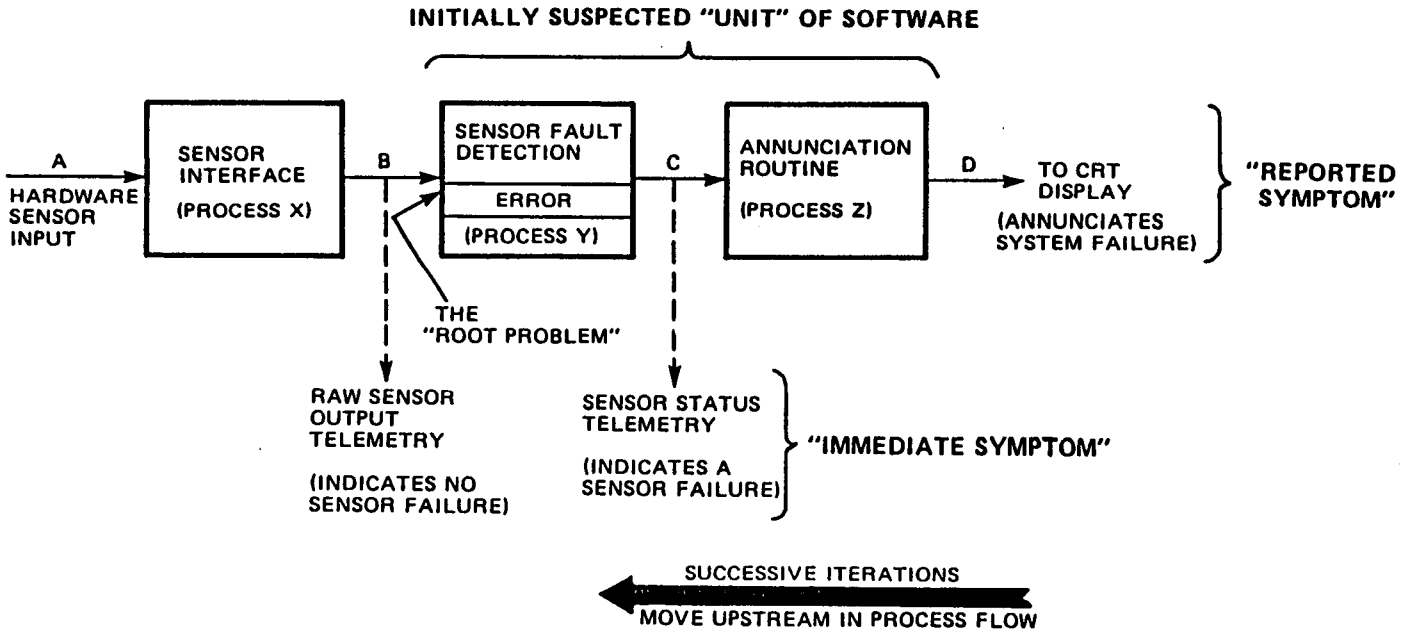


INVESTIGATION TECHNIQUES

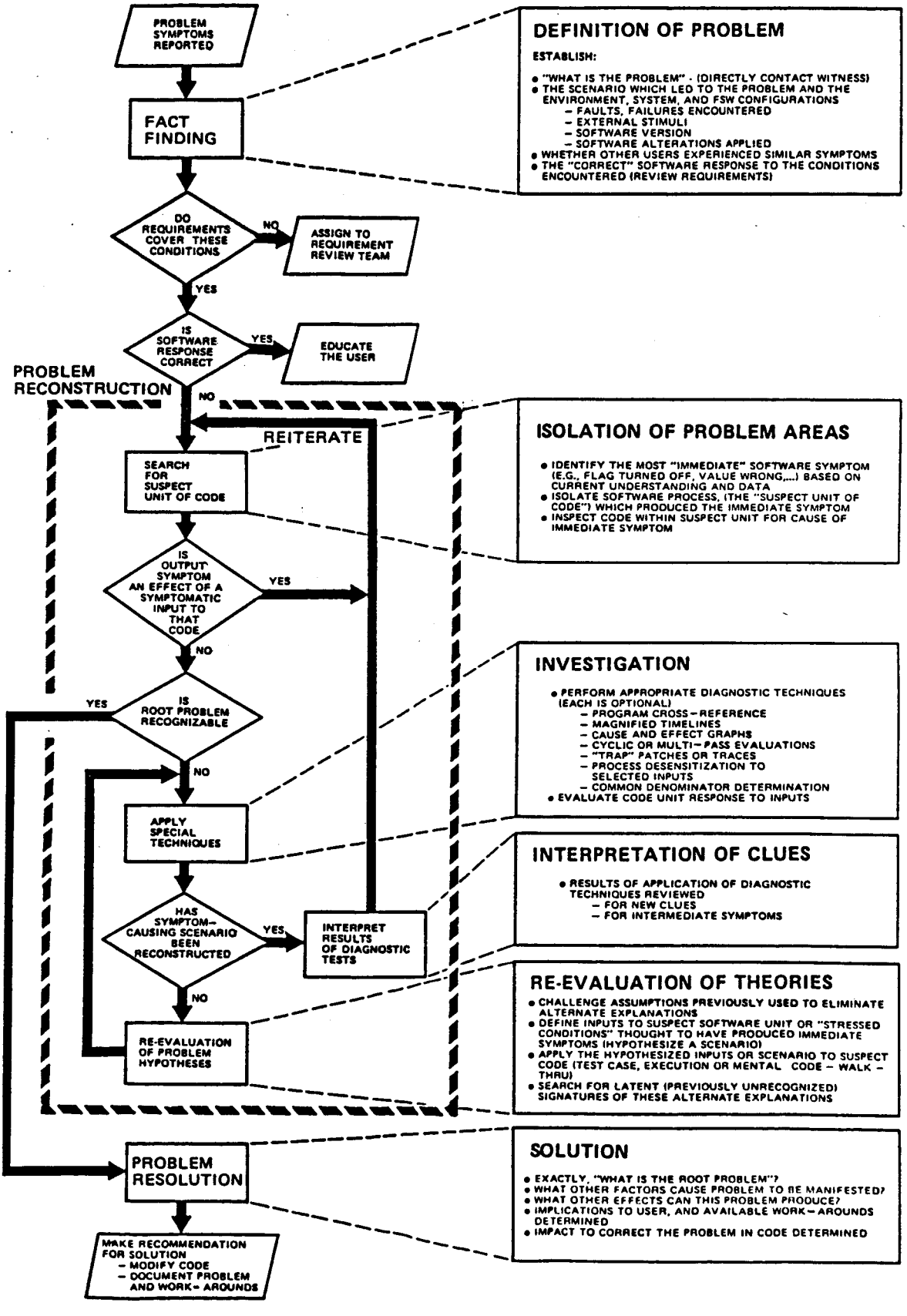
- USE APPROPRIATE DIAGNOSTIC TECHNIQUES
  - PROGRAM CROSS REFERENCE
  - MAGNIFIED TIMELINES
  - CAUSE AND EFFECT GRAPHS
  - CYCLIC/MULTIPASS EVALUATIONS
  - TRAP PATCHES/TRACES
  - PROCESS DESENSITIZATION
  - COMMON DENOMINATOR DETERMINATION

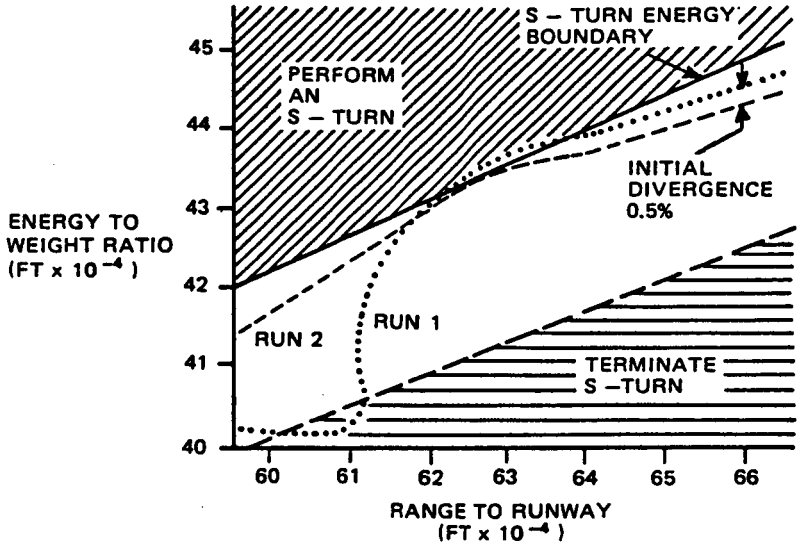
- EVALUATE FSW RESPONSE TO HYPOTHESIZED INPUTS
  - CODE WALK-THROUGH/MENTAL INSPECTION
  - EXECUTION TEST
  - REVISE HYPOTHESIS
  - CHALLENGE ASSUMPTIONS

PROBLEM ISOLATION



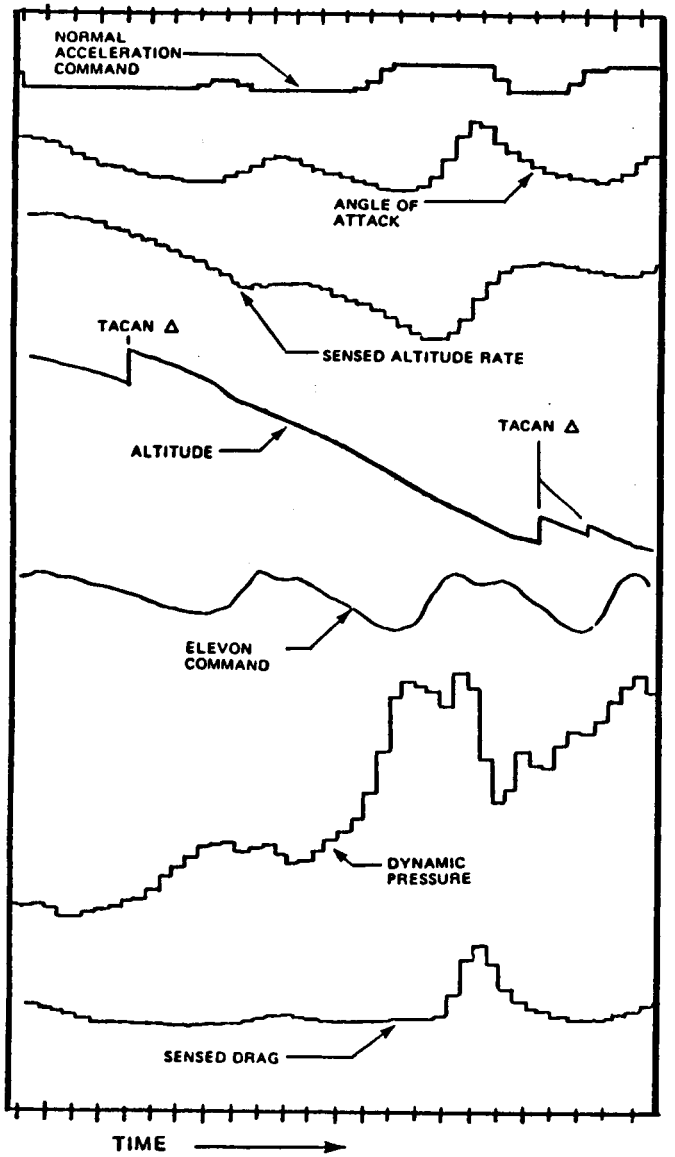
THE GN&C FSW PROBLEM ANALYSIS PROCESS

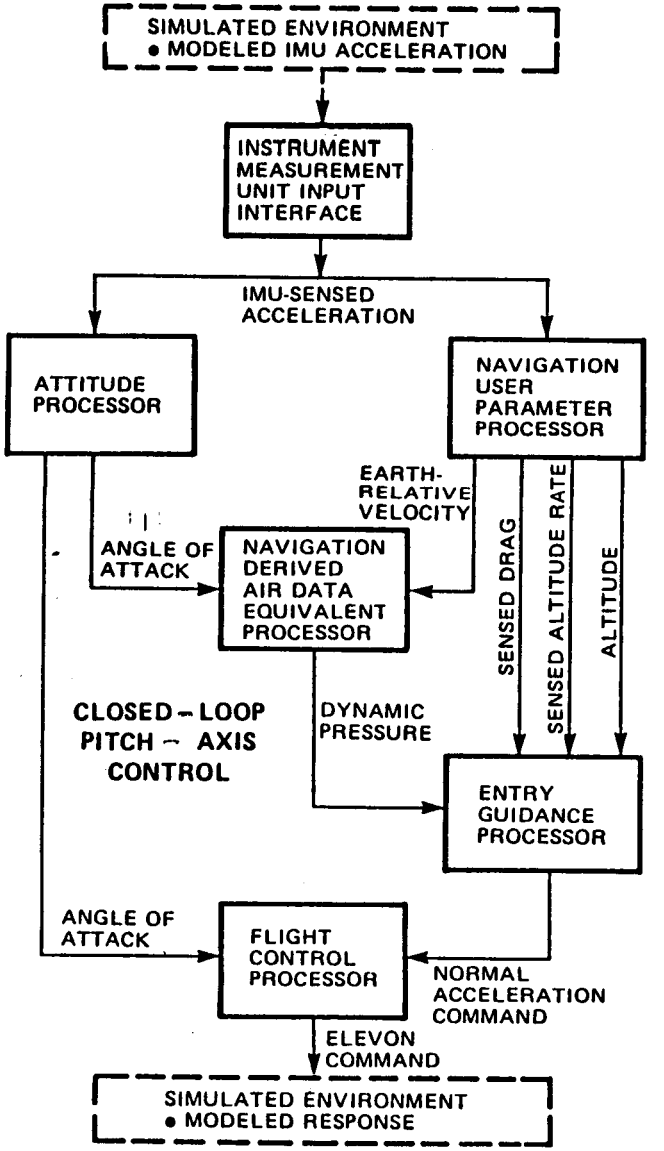




MAGNIFIED TIMELINE EXAMPLE

CAUSE AND EFFECT GRAPHING EXAMPLE

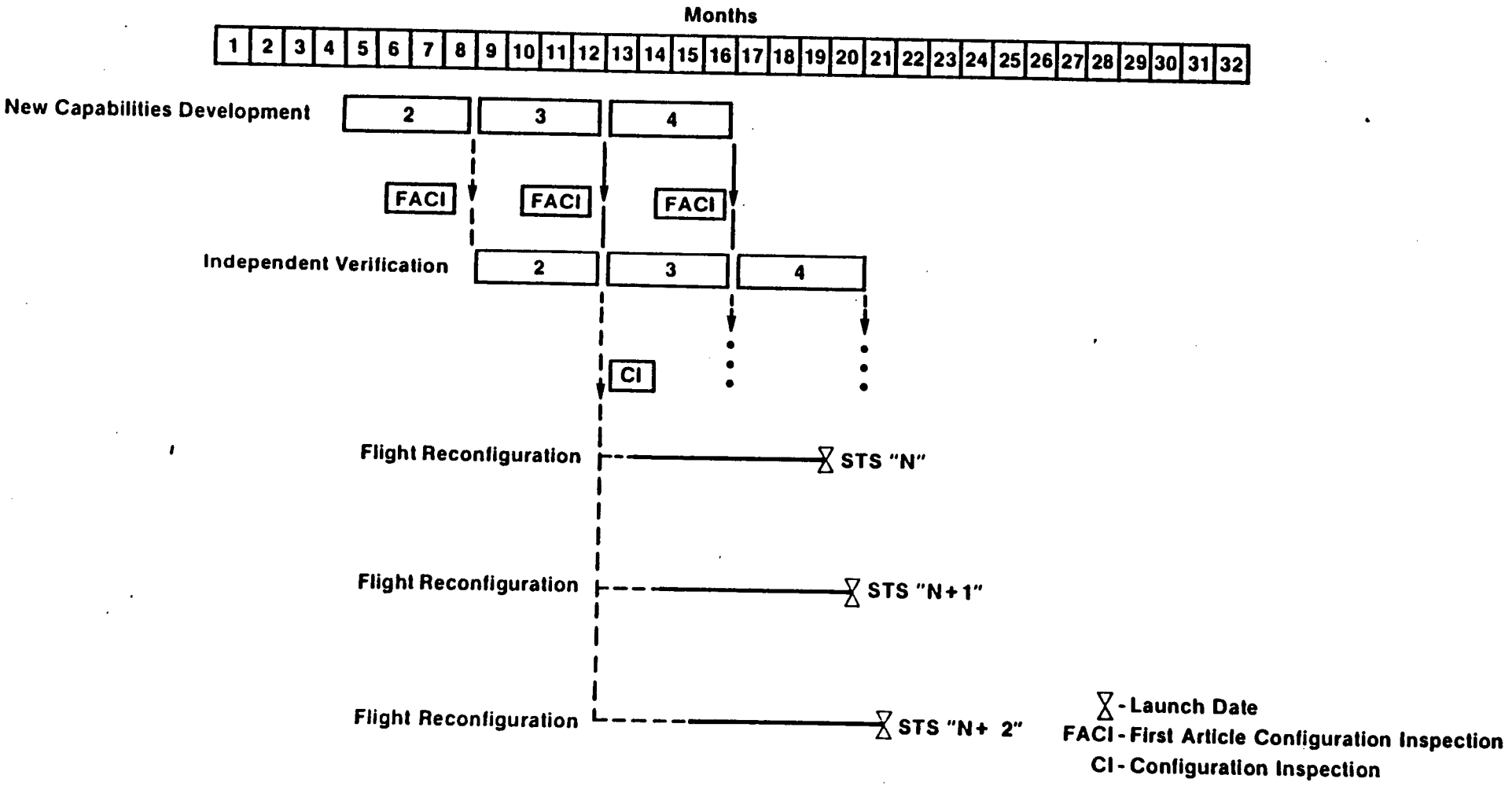




SOFTWARE RELEASES
AND
RECONFIGURATION

SOFTWARE CRITICAL TO NASA SHUTTLE

SOFTWARE RELEASES AND RECONFIGURATION

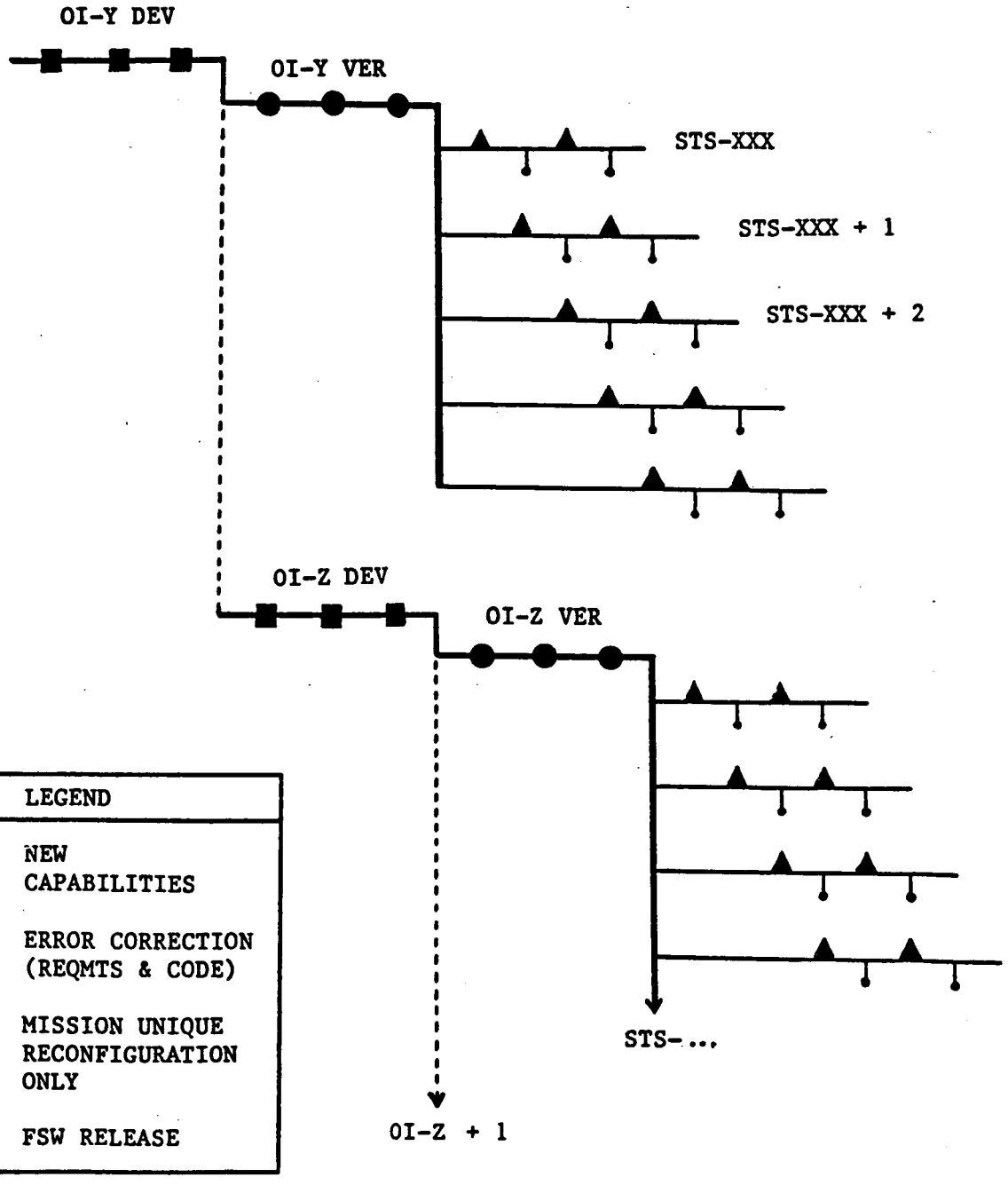


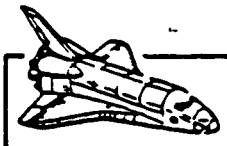
RECONFIGURATION/CERTIFICATION

- **INDEPENDENT ORGANIZATION RESPONSIBLE FOR "TAILORING" FLIGHT SOFTWARE SYSTEMS TO SPECIFIC FLIGHTS**
- **HIGHLY AUTOMATED PROCESS**
- **FUNCTIONS**
  - RECEIVE ELECTRONIC REQUIREMENTS FROM NASA (WITHIN THE SPF)
    - MISSION PROFILE DATA (CALLED I-LOADS)
    - PAYLOAD AND VEHICLE SYSTEMS DATA (CALLED LEVEL-C DATA)
    - TELEMETRY CONFIGURATION DATA (CALLED DOWNLIST)
  - REQUIREMENTS READIED FOR APPLICATION TO BASE FLIGHT SOFTWARE SYSTEMS USING AUTOMATED PRE-PROCESSOR SYSTEMS
  - PROCESSED REQUIREMENT APPLIED TO BASE FLIGHT SOFTWARE SYSTEMS USING AUTOMATED BUILD AND
  - RECONFIGURED SYSTEM TESTING
    - AUTO SCORERS
    - DETAILED TESTING IN SPF
    - FLIGHT SIMULATIONS IN SPF
  - GENERATION AND QA OF DDELIVERABLES (TAPES, DOCUMENTATION, ETC.)
- **CURRENTLY PARALLEL RECONFIGURATION IS PERFORMED BY THE STS OPERATIONS CONTRACTOR AND BY IBM (CALLED CERTIFICATION)**

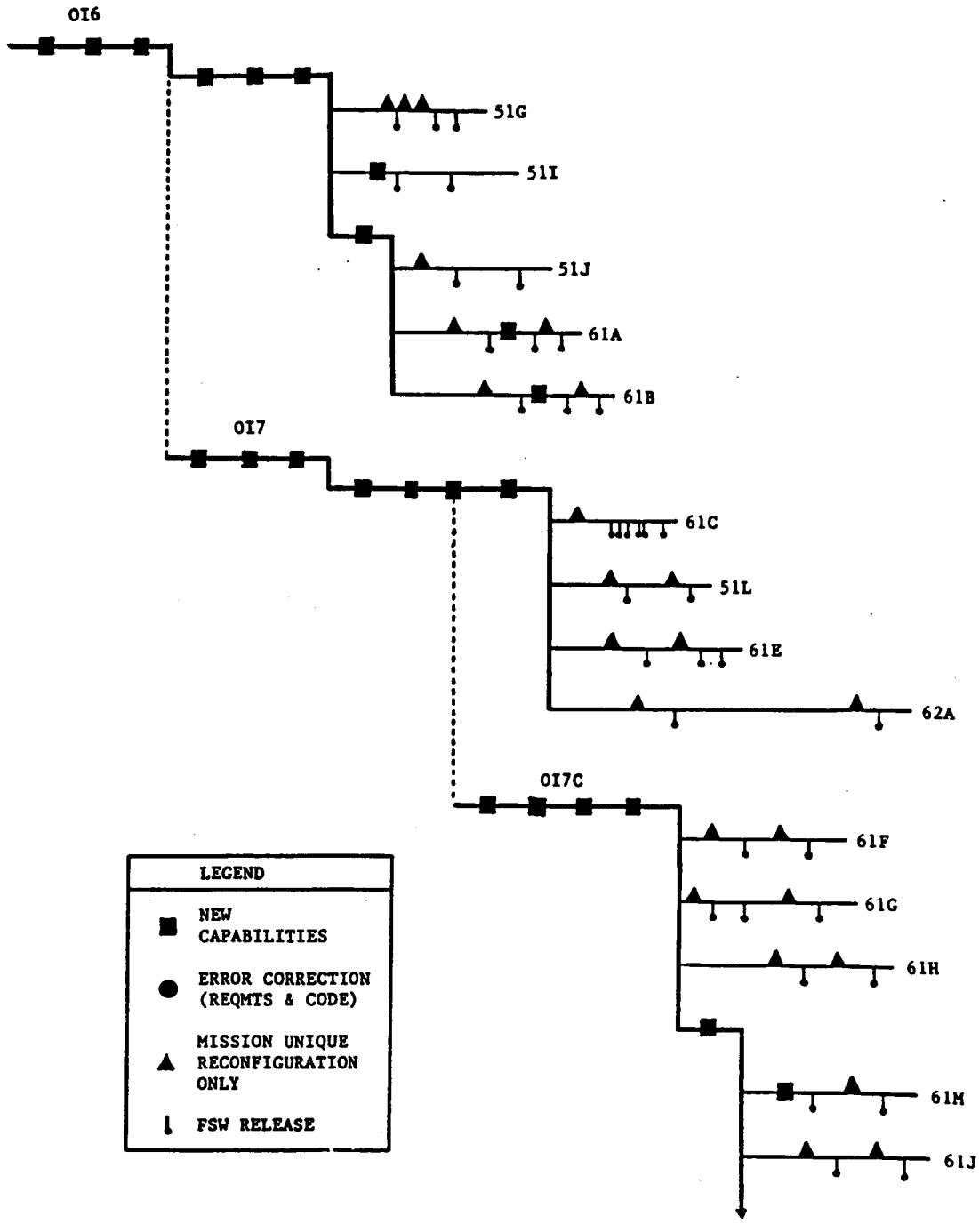
NOMINAL (IDEAL) PASS DEVELOPMENT AND RECONFIGURATION ACTIVITY

"OPERATIONAL INCREMENT PLAN/FLT-TO-FLT RECONFIGURATION PLAN"





ACTUAL PASS DEVELOPMENT AND RECONFIGURATION ACTIVITY



APPENDIX A

QUALITY/PRODUCTIVITY PROGRAMS

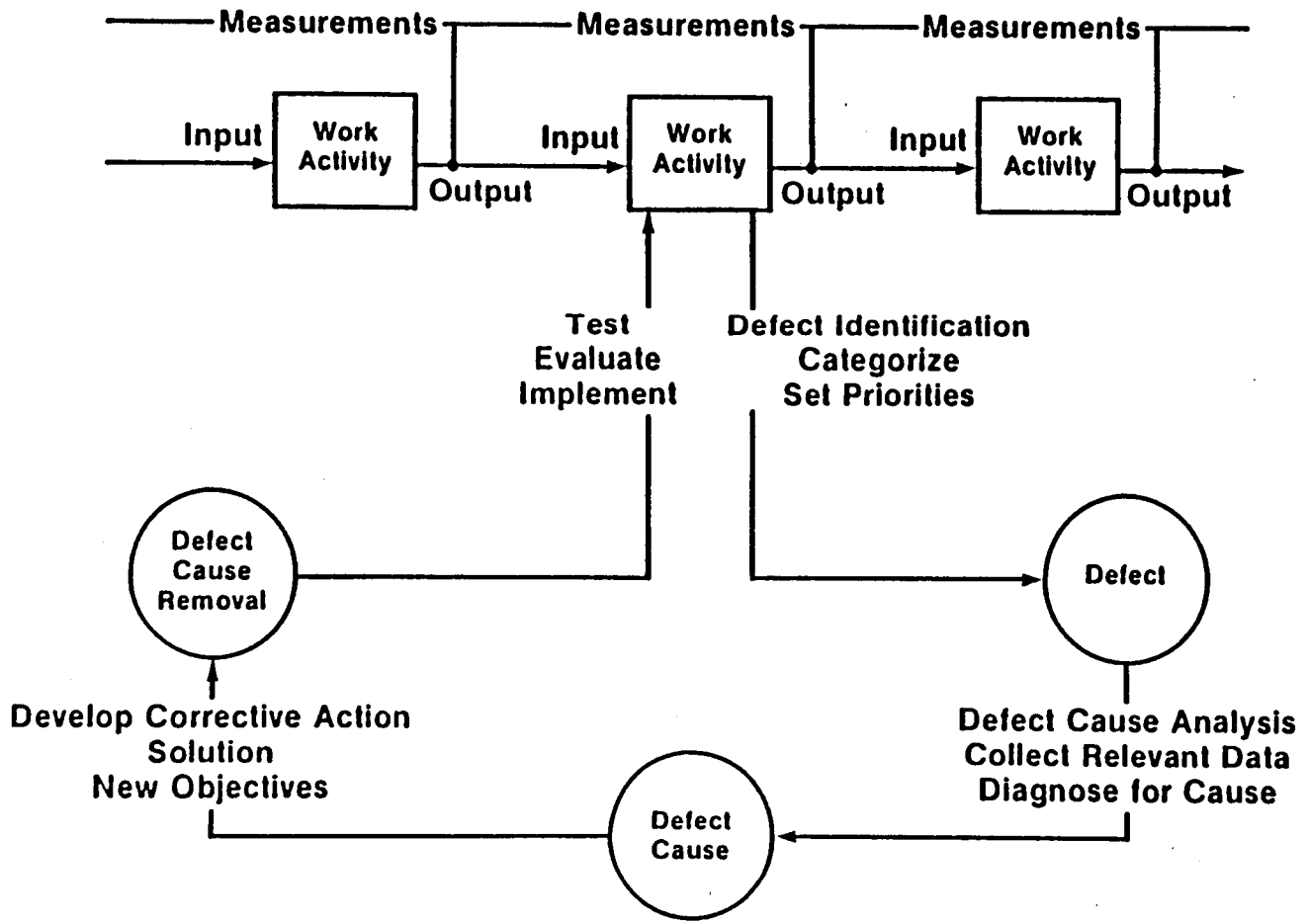
IBM QUALITY AND PRODUCTIVITY IMPROVEMENT PROGRAM

DEFECT CAUSE ANALYSIS AND REMOVAL

- Inspections of Work Products Across the Process
  - Requirements
  - Design
  - Code
  - Test
- Categorization of Defects
  - Data Collection and Retention
  - Analysis
- Defect Trend Studies
  - Escape Error Analysis
  - Process Studies Conducted By Those Involved

IBM QUALITY AND PRODUCTIVITY IMPROVEMENT PROGRAM

DEFECT REMOVAL CYCLE

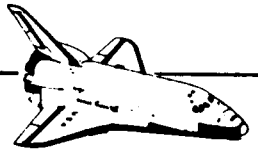


DISCREPANCY ANALYSIS PROCESS

- **EVERY DISCREPANCY IS FORMALLY REVIEWED TO DETERMINE WHETHER IT WAS MISSED BY ("ESCAPED") ANY "UPSTREAM" STEP IN THE DEVELOPMENT/VERIFICATION PROCESS**
  - — EACH AREA CONDUCTS INVESTIGATION FOR EACH OF ITS OWN "ESCAPES"
    - •• WHY PROBLEM MISSED
      - — IF HUMAN ERROR, HOW TO DETECT/CORRECT
      - — IF PROCESS ERROR, HOW TO CHANGE PROCESS
    - •• COULD OTHER OCCURRENCES OF SAME "ESCAPE" EXIST
      - — IF SO, DEFINE SCOPE OF EXPOSURE
      - — IF SO, DEFINE "AUDIT" TO IDENTIFY OTHER OCCURRENCE
  - — QUALITY DATA RECORDED FOR FUTURE REFERENCE (CONFIGURATION MGMT DATA BASE)
    - •• CHANGE BEING MADE WHEN ERROR INTRODUCED
    - •• TYPE OF ERROR MADE
    - •• REASONS MISSED
    - •• SEVERITY OF ERROR IN FLIGHT IF NOT FIXED
  - — DISCREPANCY HISTORY STUDIED FOR TRENDS/PATTERNS/COMMON TYPES

- **PROCESS AND PROCEDURES ARE THEN AUGMENTED TO DEFENSE AGAINST FUTURE "ESCAPES" OF KNOWN PROBLEMS (AREA BY AREA)**

- **RESULTS OF ALL DISCREPANCY OVERSIGHT ANALYSES REVIEWED QUARTERLY WITH CONTRACTOR AND NASA MANAGEMENT**
  - — DISCREPANCY "ESCAPE/DETECTION" HISTORY PRESENTED (ANALYZED)



QUALITY MEASUREMENT DEFINITIONS

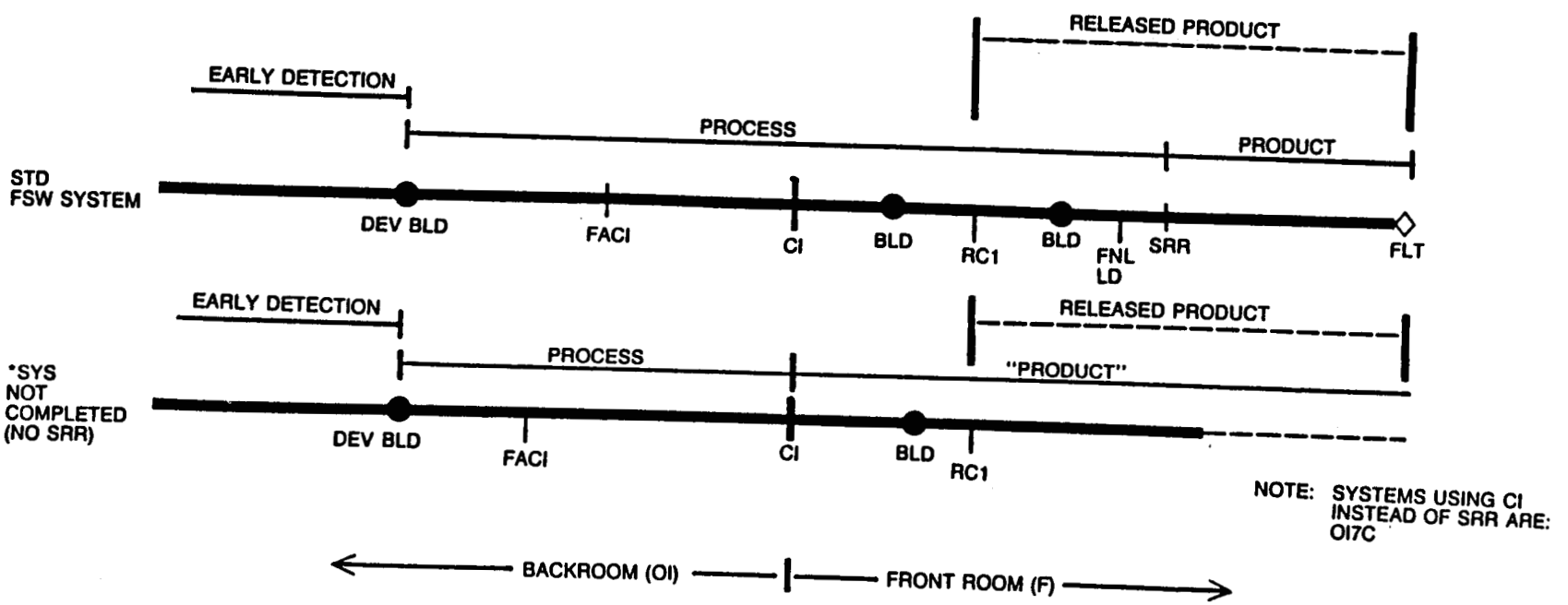
IBM OBS QUALITY MEASUREMENT DEFINITIONS

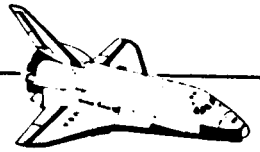
$$\text{EARLY DETECTION \%} = \frac{\text{NUMBER OF MAJOR INSPECTION ERRORS}}{\text{NUMBER OF MAJOR INSPECTION ERRORS + VALID DRs}} \times 100$$

$$\text{PROCESS ERROR RATE} = \frac{\text{NUMBER OF VALID DRs DURING DEVELOPMENT CYCLE THROUGH SRR (OR CI*)}}{\text{THOUSAND NEW, CHANGED, OR DELETED SOURCE LINES OF CODE}}$$

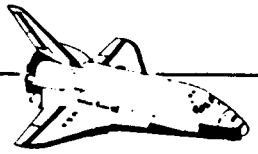
$$\text{PRODUCT ERROR RATE} = \frac{\text{NUMBER OF VALID DRs POST COMPLETION (SRR OR CI*)}}{\text{THOUSAND NEW, CHANGED, OR DELETED SOURCE LINES OF CODE}}$$

RELEASED PRODUCT ERRORS = NUMBER OF VALID DRs AGAINST NEW OR CHANGED CODE WHICH WERE FOUND AFTER RELEASE AND ARE PRECEIVABLE BY USERS (SEV 1-3)





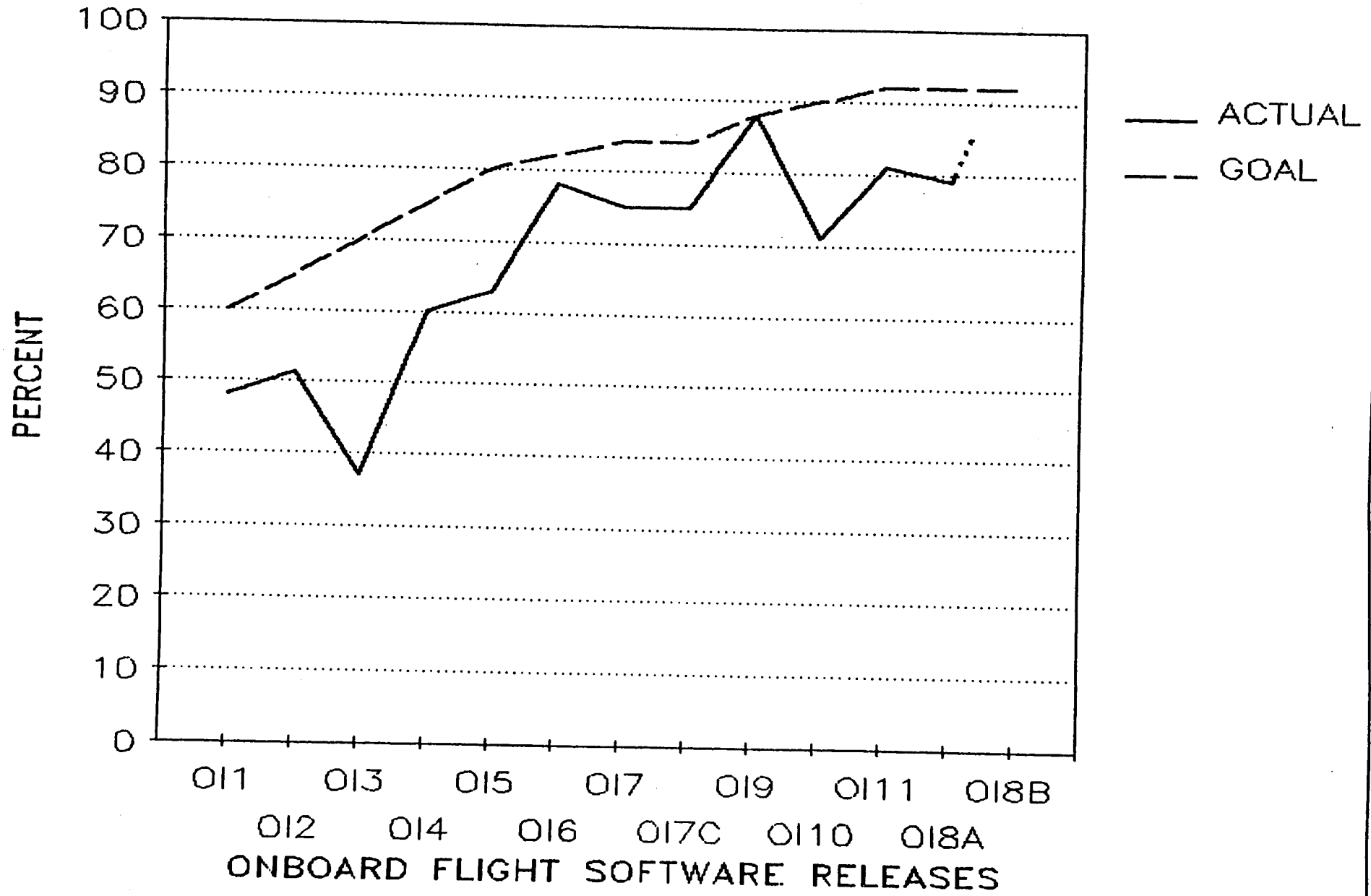
QUALITY MEASUREMENTS



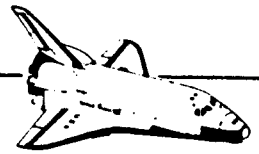
EARLY DETECTION

-- WHAT PERCENT OF ALL ERRORS MADE WERE FOUND AND ELIMINATED BEFORE BEING IMPLEMENTED INTO THE FSW?

EARLY DETECTION



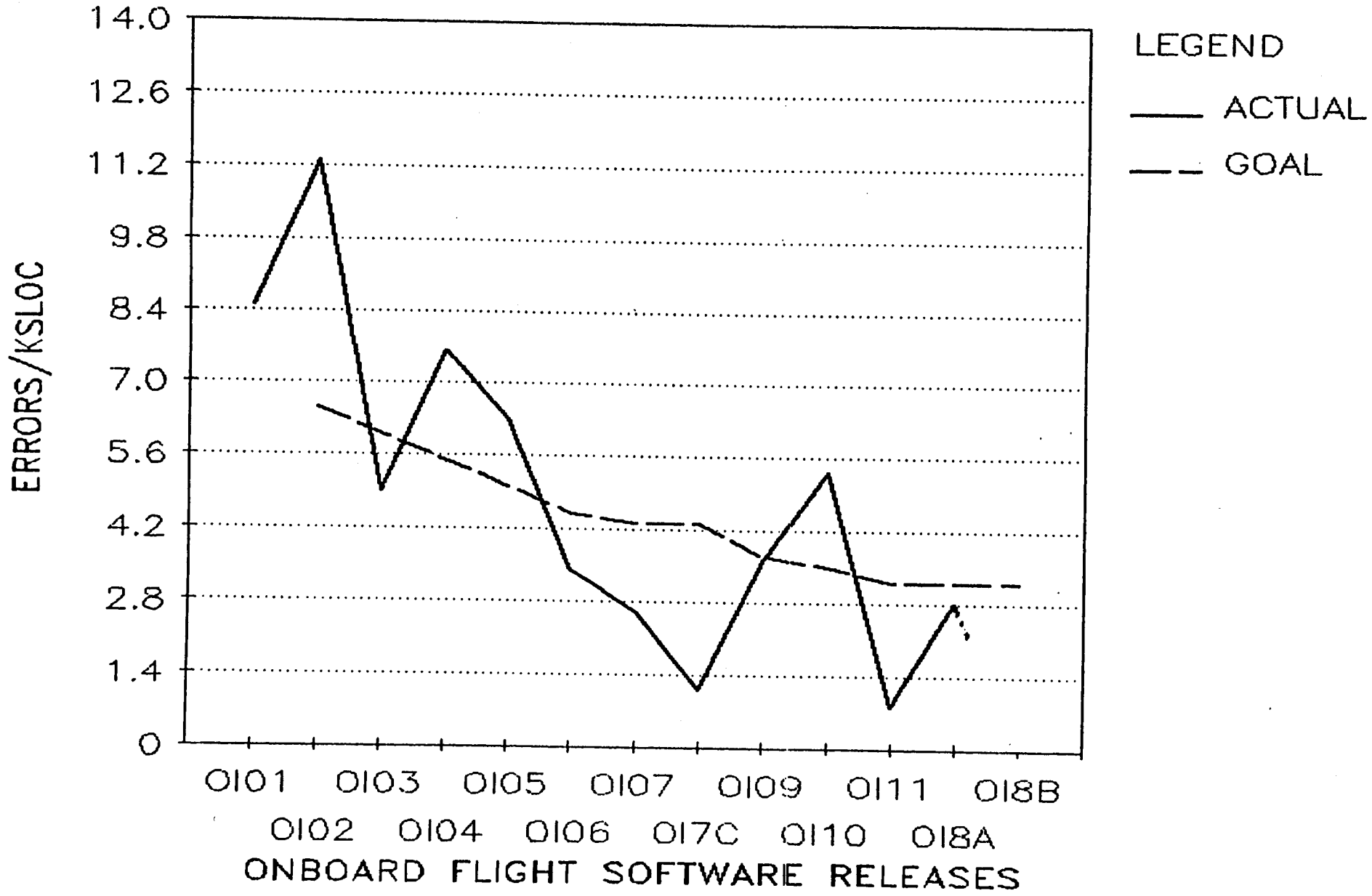
6/22/87 CMDB



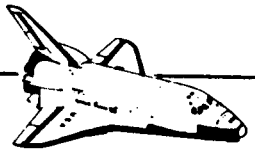
PROCESS ERROR RATE

-- HOW MANY ERRORS WERE MADE IN THE FSW BUT WERE FOUND BEFORE FLIGHT?

PROCESS ERROR RATE



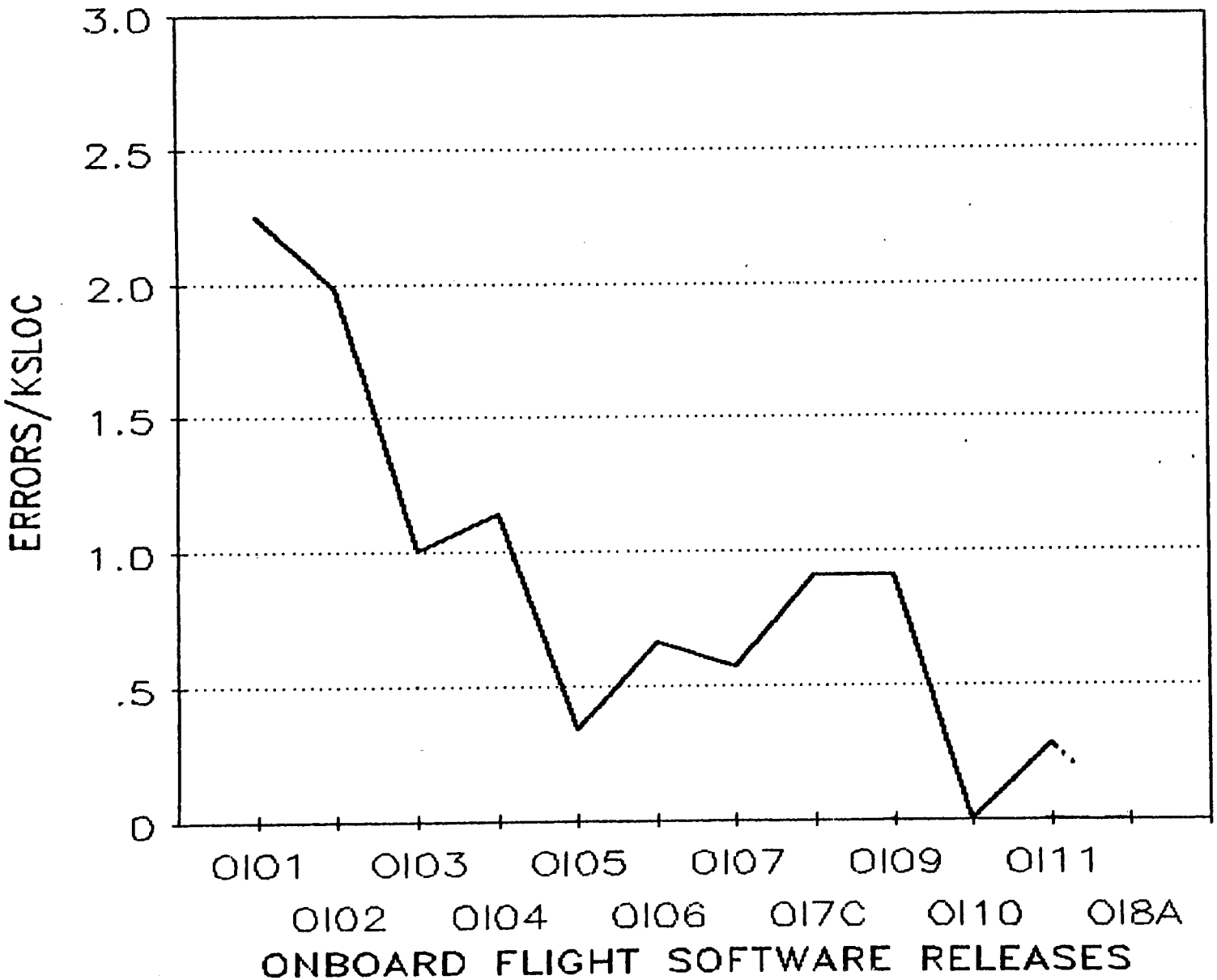
6/22/87 CMDB



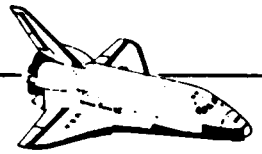
PRODUCT ERROR RATE

-- HOW MANY ERRORS DID OUR PROCESS MISS?

PRODUCT ERROR RATE



6/22/87 CMDB



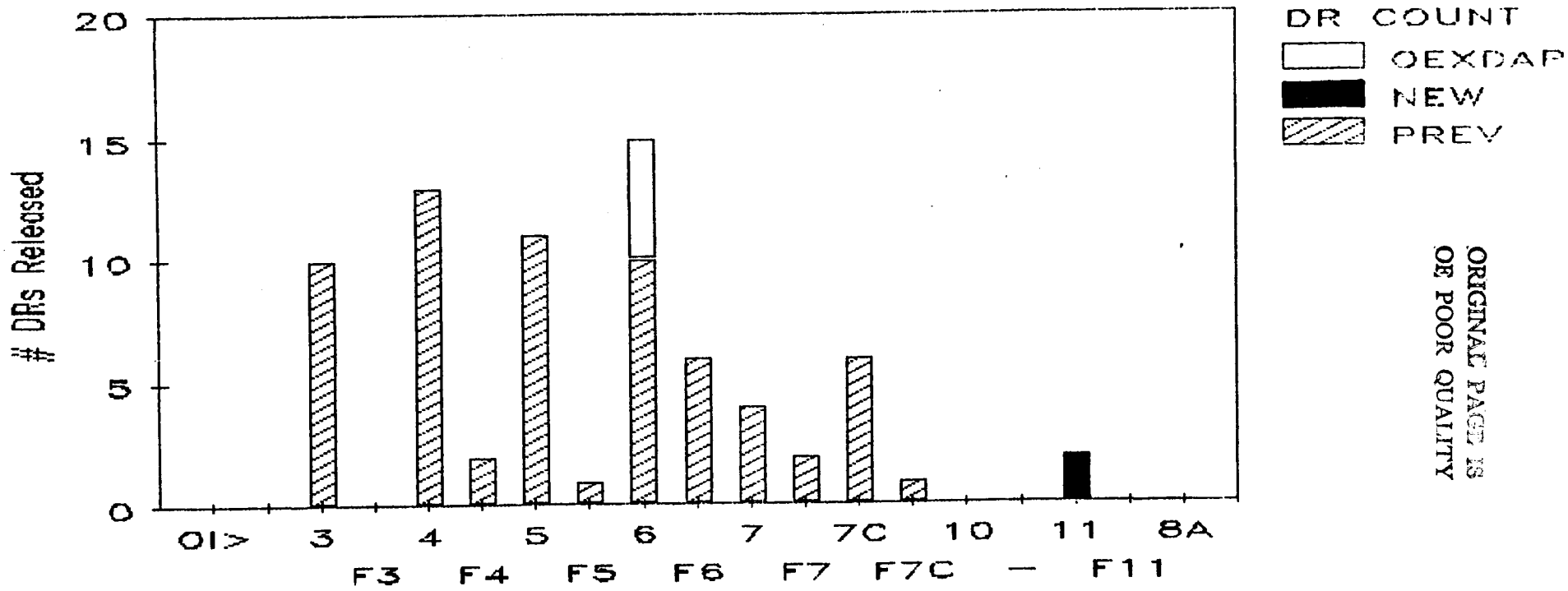
'RELEASED' PRODUCT ERRORS

-- A MEASURE OF CUSTOMER SATISFACTION

TOTAL CLASS 1 RELEASED PRODUCT ERRORS

AS OF 7/7/87

Not Including 2 New DRs Found Against Pre-013 FSW Since 3/87



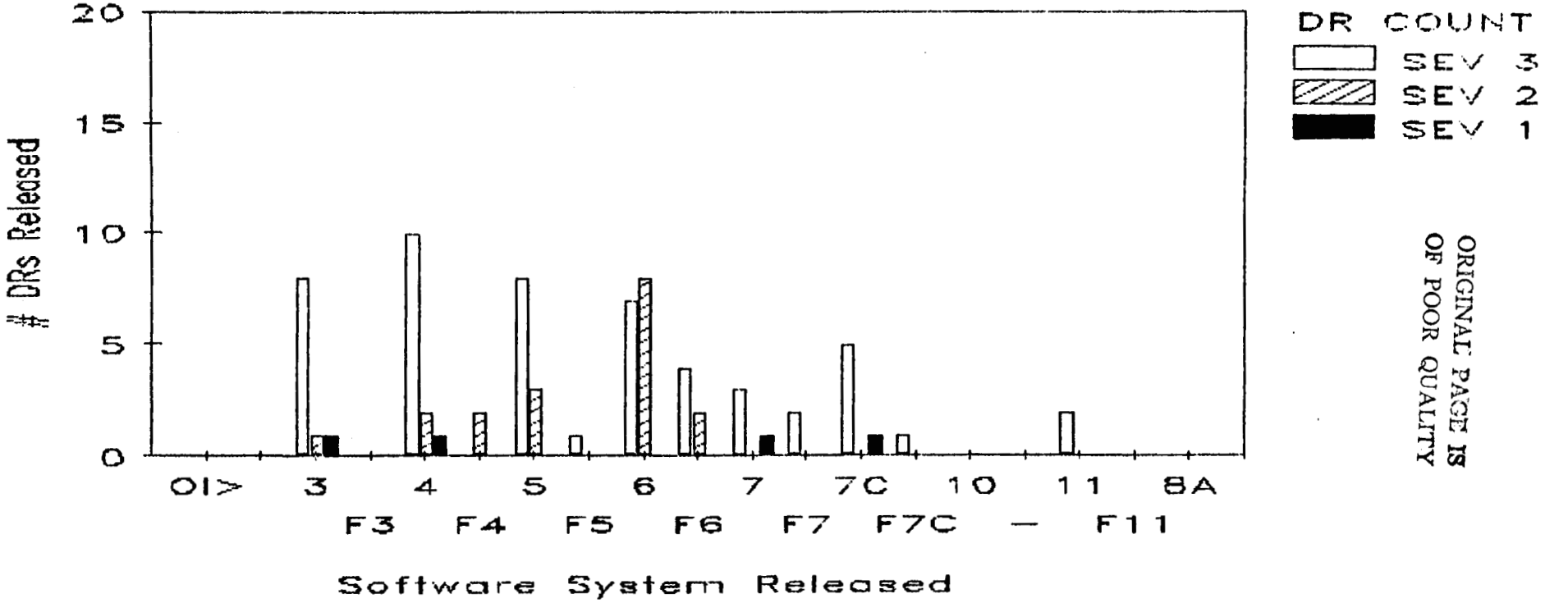
Fn Denotes Class 1 DRs in Frontroom for OIn Specified to Left.

TOTAL CLASS 1 RELEASED PRODUCT ERRORS

AS OF 7/7/87

SEVERITY DISTRIBUTION

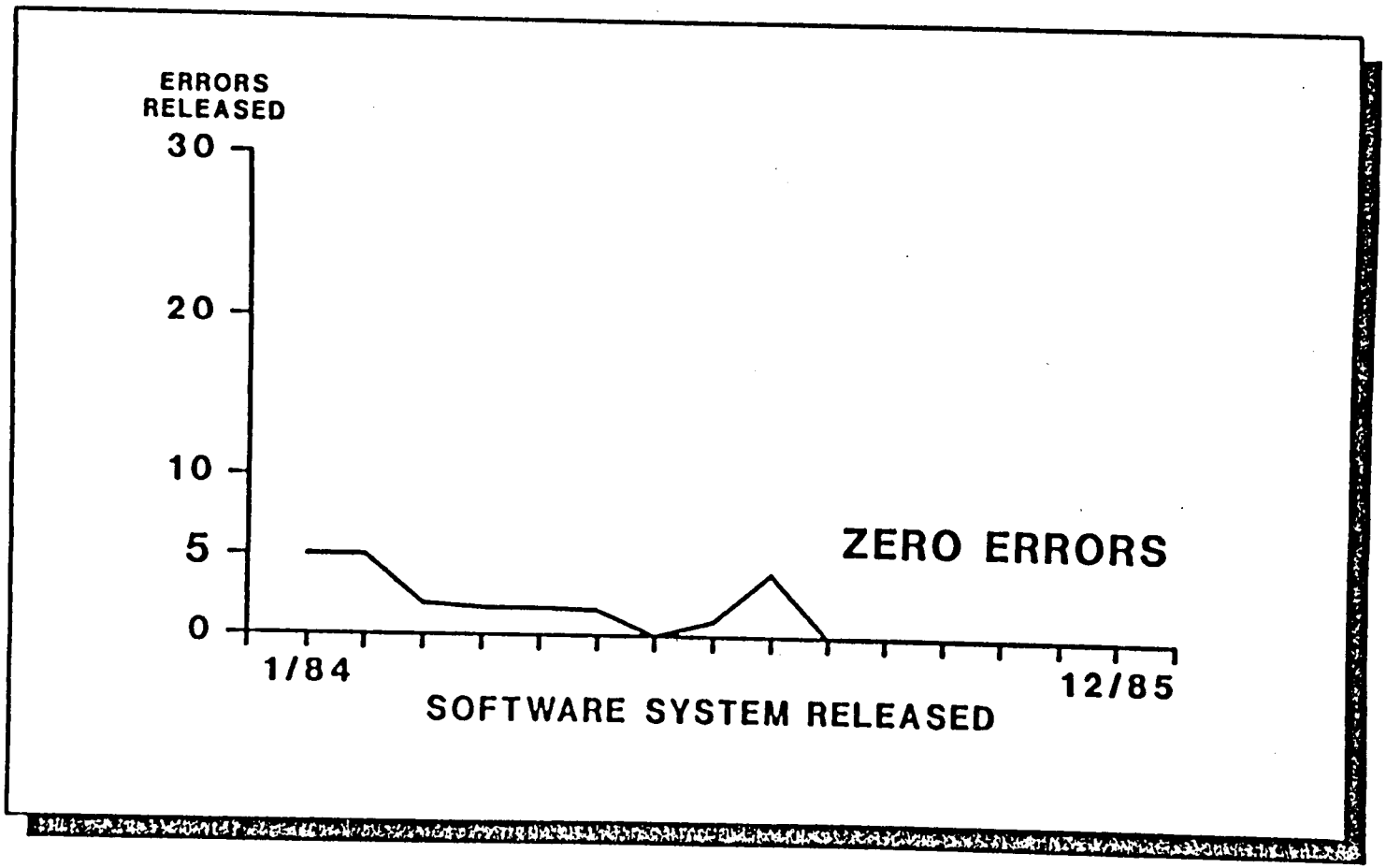
Not Including 2 New DRs Found Against Pre-013 FSW Since 3/87



Fn Denotes Class 1 DRs in Frontroom for OIn Specified to Left.

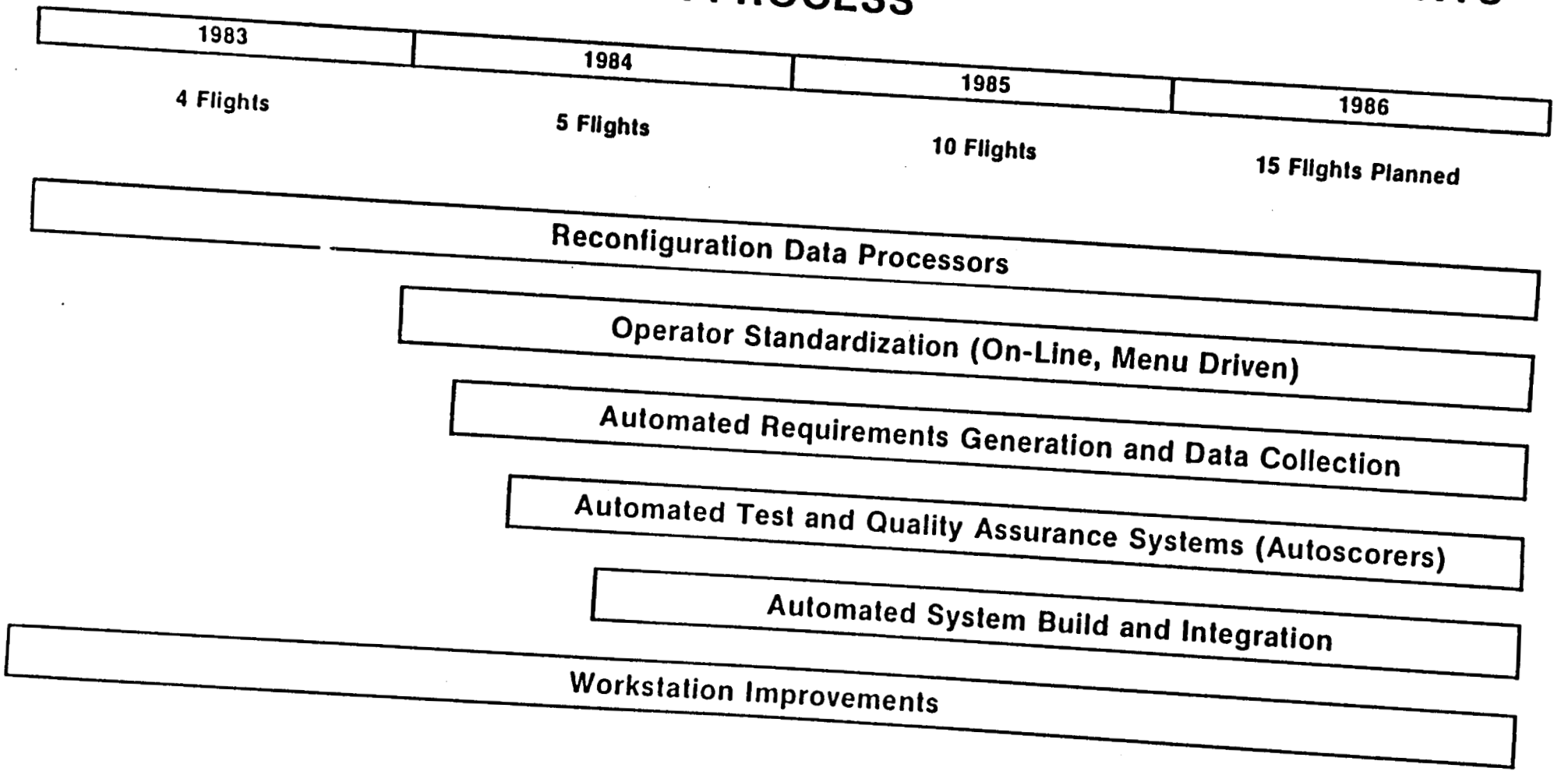
SOFTWARE QUALITY AND PRODUCTIVITY MEASUREMENTS

RECONFIGURATION ERRORS PER RELEASED SYSTEM



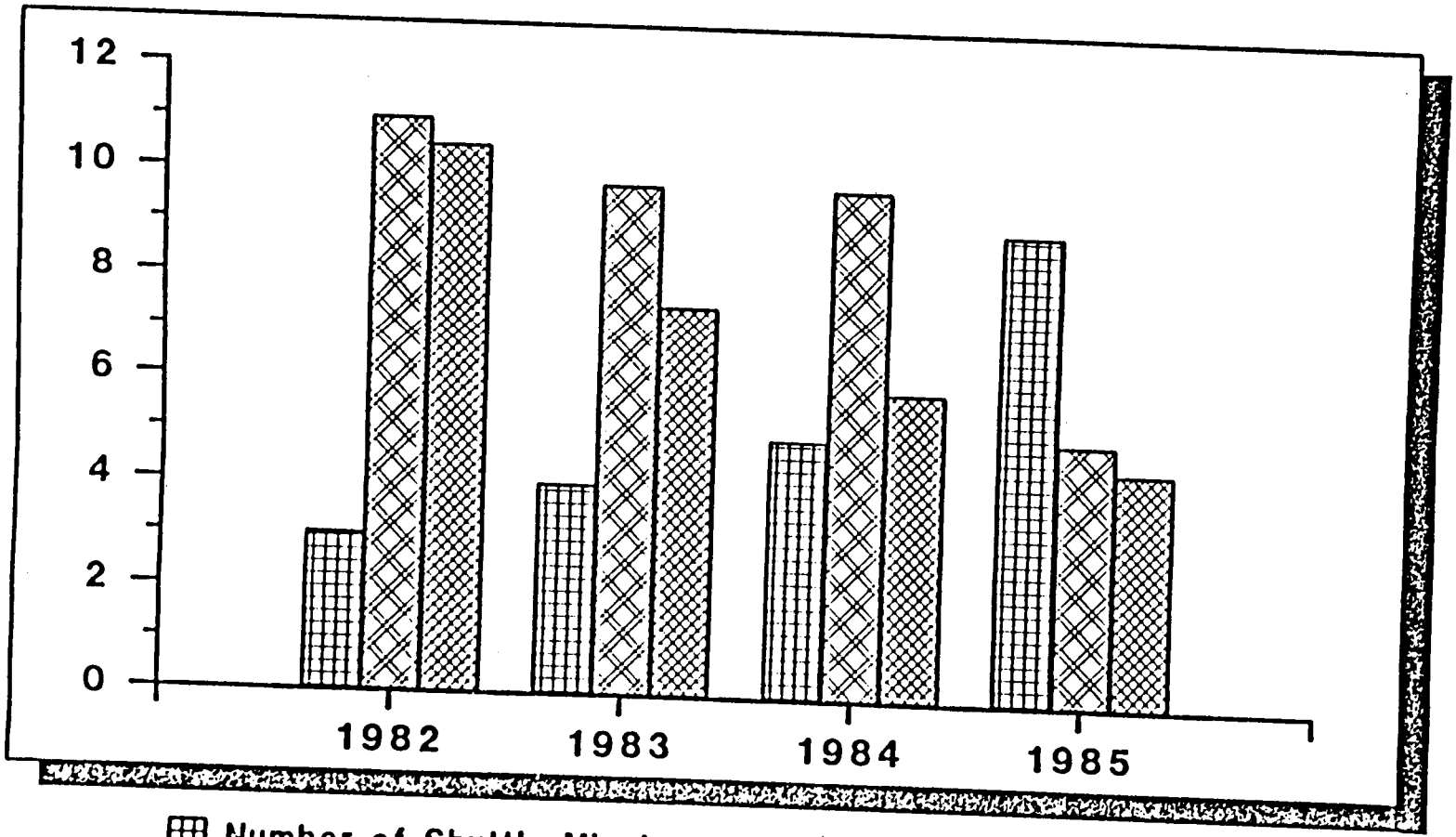
SOFTWARE QUALITY AND PRODUCTIVITY MEASUREMENTS

AUTOMATED SOFTWARE TOOLS AND PROCESS IMPROVEMENTS IN THE RECONFIGURATION PROCESS



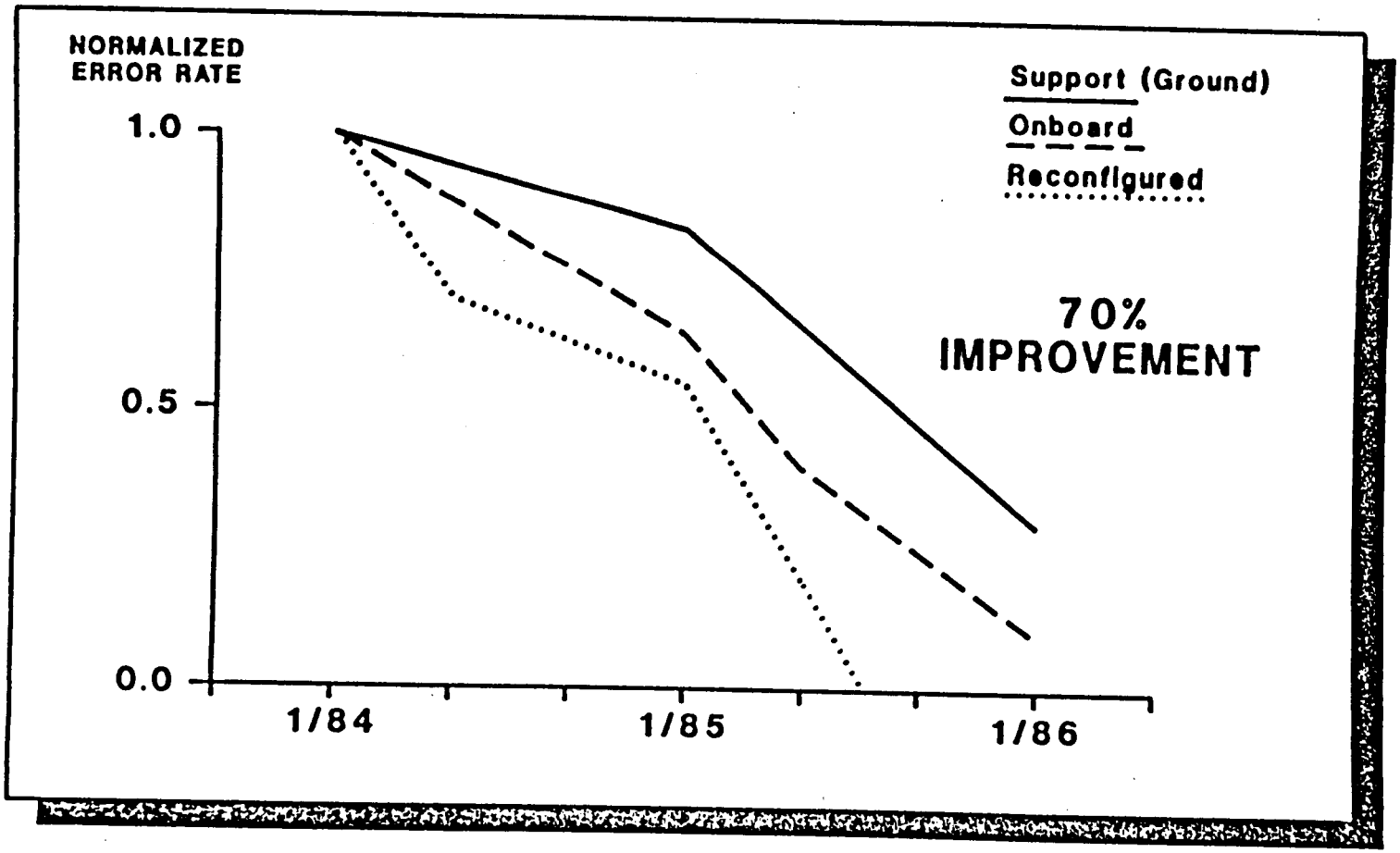
SOFTWARE QUALITY AND PRODUCTIVITY MEASUREMENTS

ONBOARD SHUTTLE SOFTWARE RECONFIGURATION PRODUCTIVITY IMPROVEMENTS



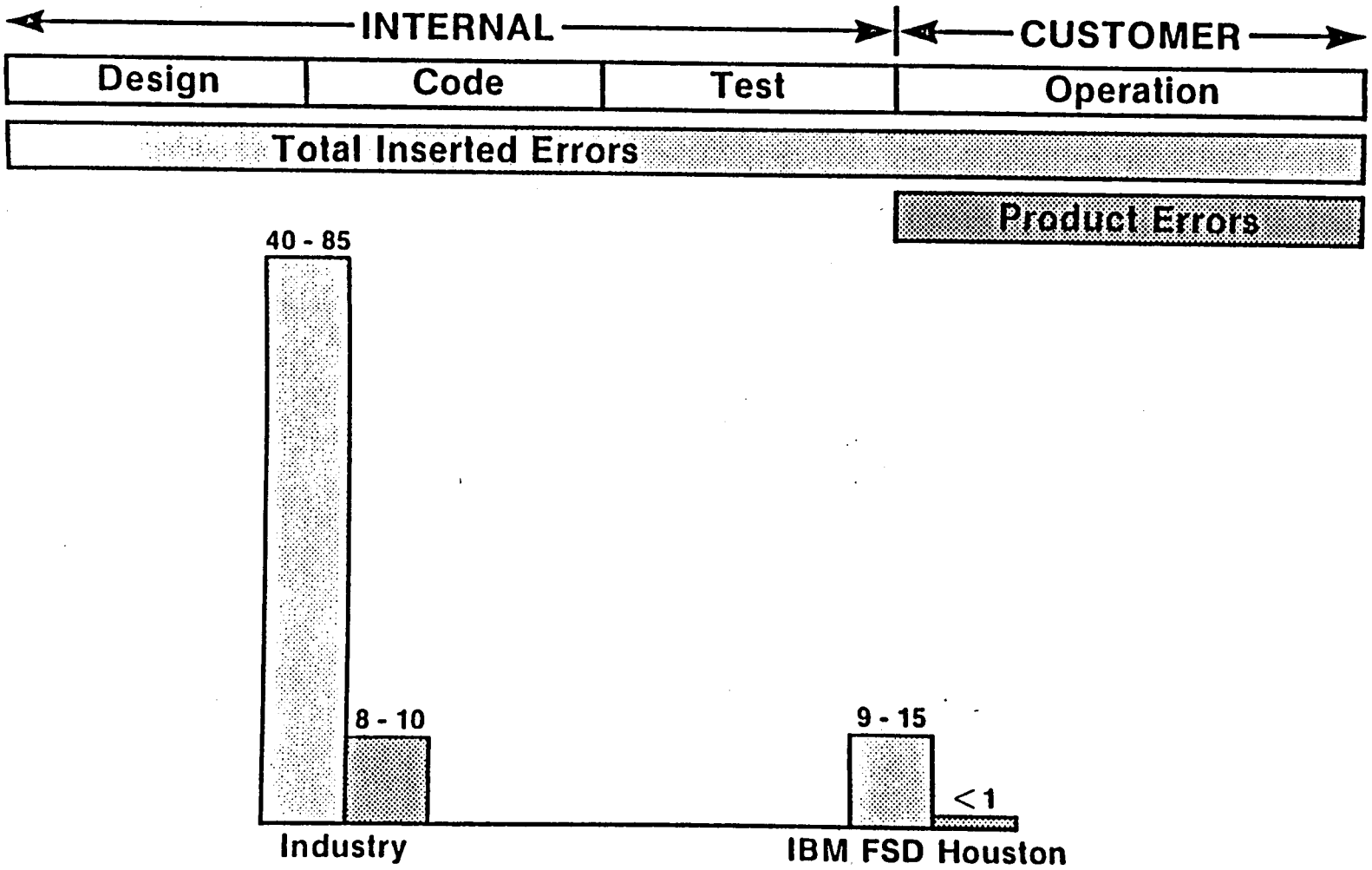
SOFTWARE QUALITY AND PRODUCTIVITY MEASUREMENTS

SHUTTLE SOFTWARE RELATIVE QUALITY IMPROVEMENTS



SOFTWARE QUALITY AND PRODUCTIVITY MEASUREMENTS

SOFTWARE QUALITY IS AN IBM FSD STRENGTH



SOFTWARE QUALITY AND PRODUCTIVITY MEASUREMENTS

- Onboard Shuttle Software Quality Measurements Show Significant Improvement
- Onboard Shuttle Software Quality Among Highest in the Industry
- Shuttle Software Reconfiguration Productivity Increased Over 50%
- Onboard Shuttle Software Achievements Result From Commitment to Zero Errors

APPENDIX B

SOFTWARE DEVELOPMENT/PRODUCTION FACILITIES

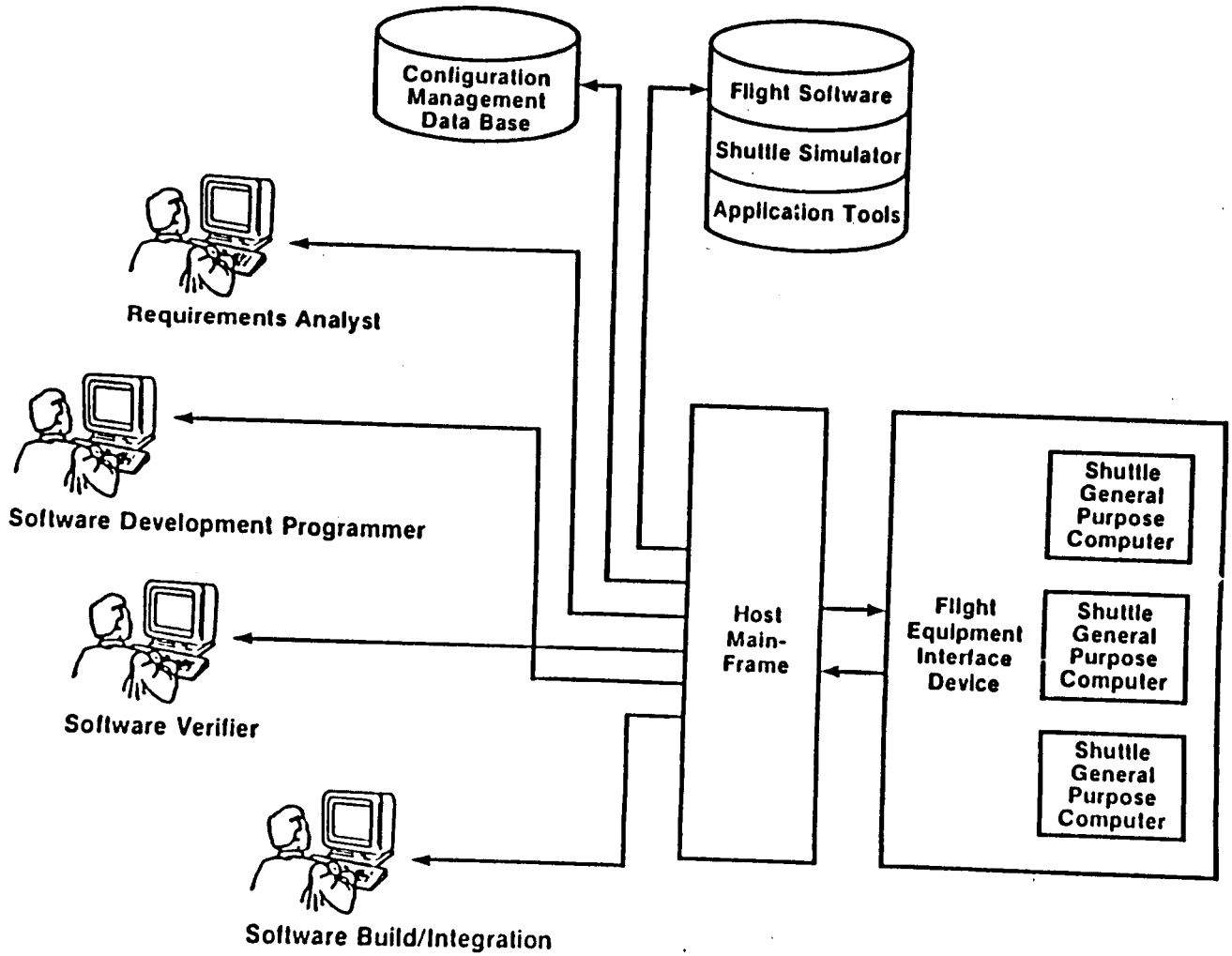
SOFTWARE CRITICAL TO NASA SHUTTLE

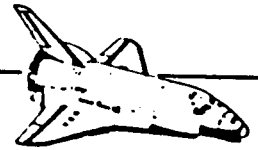
SOFTWARE DEVELOPMENT AND PRODUCTION FACILITY

- Mainframe Host Computers, Extensive Direct Access Disk Storage, Shuttle General Purpose Computers And Interfaces Necessary for Testing
- Access Via Terminals for Software Developers and NASA Community
- Software Consists of All Tools Necessary to Develop And Reconfigure the Software
  - Application Tools
  - Shuttle Simulator
  - Flight Software
  - Configuration Management Data Base
- Configuration Management Data Base is the Repository for All Project Control and Descriptive Information

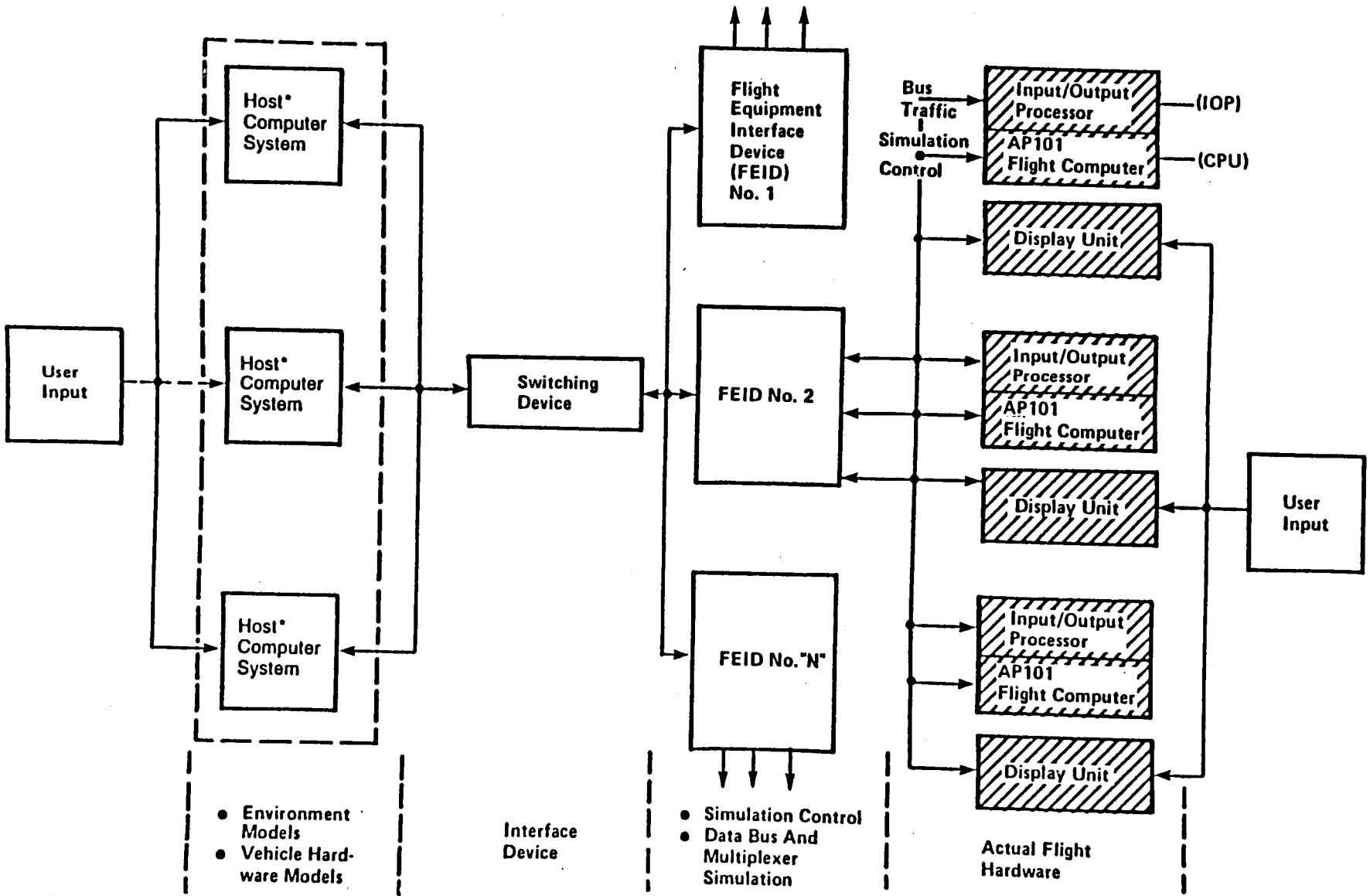
SOFTWARE CRITICAL TO NASA SHUTTLE

ONBOARD SHUTTLE SOFTWARE DEVELOPMENT





SOFTWARE DEVELOPMENT/PRODUCTION FACILITY FLIGHT SIMULATOR



* Commercial Processors

APPENDIX C

ACRONYMS

ACRONYMS

BCLMAKER	BUILD CONTROL LIST MANAGER
BFS	BACKUP FLIGHT SYSTEM
BFSPLP	BFS PAYLOAD PREPROCESSOR
CCB	CONFIGURATION CONTROL BOARD
CI	CONFIGURATION INSPECTION
CIP	CLASS 1 INTEGRATION PLAN
CITE	CARGO INTEGRATION TEST EQUIPMENT
CLASS 1	FSW CAPABILITY UPDATE
CMC	CONFIGURATION MANAGEMENT & CONTROL
CMDB	CONFIGURATION MANAGEMENT DATA BASE
CPU	CENTRAL PROCESSING UNIT
CR	CHANGE REQUEST (Used Interchangeably With SCR)
CSECT	CONTROL SECTION
DBA	DATA BASE ADMINISTRATOR
DCCB	DATA CONFIGURATION CONTROL BOARD
DCR	DATA CHANGE REQUESTS
DDRB	DEVELOPMENT DISCREPANCY REVIEW BOARD
DL OR D/L	DOWNLIST
DLP	DOWNLIST PREPROCESSOR
DPSD	DATA PROCESSING SYSTEM DIVISION
DR	DISCREPANCY REPORT FOR FSW
DSN	DATA SET NAME
FACI	FIRST ARTICLE CONFIGURATION INSPECTION
FCCB	FACILITIES CHANGE CONTROL BOARD
FEID	FLIGHT EQUIPMENT INTERFACE DEVICE

FLPS	FLIGHT LOAD PREPARATION SYSTEM
FRF	FLIGHT READINESS FIRING
FSW	FLIGHT SOFTWARE
GFE	GOVERNMENT FURNISHED EQUIPMENT/INFORMATION
GMEM	GENERAL MEMORY READ/WRITE PROCEDURE
GTL	GENERIC TRAINING LOAD
HDW	HARDWARE
HSM	HIERARCHICAL STORAGE MANAGEMENT
IBCB	INTEGRATED BASELINE CONTROL BOARD
IBM	INTERNATIONAL BUSINESS MACHINES
IDRB	INTEGRATED DISCREPANCY REVIEW BOARD
IDS	ILOAD DATA SET
IL OR I/L	INITIALIZATION LOAD
IMRB	INTERIM MASTER RECONFIGURATION BASE
IMS	INFORMATION MANAGEMENT SYSTEM
JES	JOB ENTRY SUBSYSTEM
JSC	JOHNSON SPACE CENTER
KSC	KENNEDY SPACE CENTER
L6	LEVEL 6 DETAIL FUNCTIONAL TESTING
L7	LEVEL 7 CAPABILITIES PERFORMANCE TESTING
L8	LEVEL 8 RECONFIGURATION PERFORMANCE TESTING
MAST	MEASUREMENT AND STIMULUS DATA BASE
MCC	MISSION CONTROL CENTER
MDBINIT	MEMBER DATABASE INITIALIZATION
MIP	MASS MEMORY INTEGRATION PLAN
MM	MASS MEMORY
MMI	MASS MEMORY IMAGE

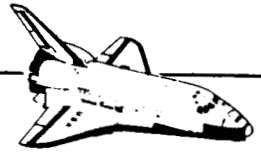
MMU	MASS MEMORY UNIT
MOCRB	MISSION OPERATIONS CHANGE REVIEW BOARD
MOD	MISSION OPERATIONS DIRECTORATE
MODRB	MISSION OPERATIONS DISCREPANCY REVIEW BOARD
MRAS	MAINTENANCE RELEASE AUTHORIZATION
MRB	MASTER RECONFIGURATION BASE
MSFC	MARSHALL SPACE FLIGHT CENTER
MVS	MULTIPLE VIRTUAL STORAGE
OASCB	ORBITER AVIONICS SOFTWARE CONTROL BOARD
OI	OPERATIONAL INCREMENT (BASE FSW SYSTEM)
ORG	ORGANIZATION
OSDR	OPERATION SHUTTLE DATA RECONFIGURATION
PASS	PRIMARY AVIONICS SOFTWARE SUBSYSTEM
PCO	PATCH CUT-OFF
PCR	PROGRAM CHANGE REQUEST
PRCB	PROGRAM REQUIREMENTS CONTROL BOARD
PRN	PROGRAM RELEASE NOTICE
PSCR	PRODUCTION SOFTWARE CHANGE REQUEST
PSDR	PRODUCTION SOFTWARE DISCREPANCY REPORT
PSF	PARAMETER SPECIFICATION FILE
R & E	RESEARCH AND ENGINEERING
RASS	RELEASE AUTHORIZATION SIGNATURE SHEET
RCV	RECEIVING
RECON	RECONFIGURATION (FLIGHT-TO-FLIGHT)
RELAUTH	RELEASE AUTHORIZATION
RI/D	ROCKWELL INTERNATIONAL/DOWNEY
RM	ROOM (AS IN FRONTROOM OR BACKROOM)

ACRONYMS

RSD	RECONFIGURATION SYSTEMS DEVELOPMENT
RSOC	ROCKWELL SHUTTLE OPERATIONS COMPANY
RT & O	RECON TEST & OPERATIONS CONTROL BOARD
SAS	SOFTWARE APPROVAL SHEET
SCCB	SOFTWARE CONFIGURATION CONTROL BOARD
SCR	SOFTWARE (CAPABILITY) CHANGE REQUEST
SDF	SOFTWARE DEVELOPMENT FACILITY
SM	1. SYSTEM MANAGEMENT AS IN "SM FSW" 2. SUBMIT TRANSACTION AS IN "SUBMIT TOOL ELEMENT VIA SM TRANSACTIONS IN IMS"
SMP	SYSTEMS MANAGEMENT PREPROCESSOR
SPF	SOFTWARE PRODUCTION FACILITY
SPIF	SHUTTLE PAYLOAD INTEGRATION FACILITY
SPT	SUPPORT
SRC	SOURCE
SRR	SOFTWARE READINESS REVIEW
SSD	SPACECRAFT SOFTWARE DIVISION
SSDR	SUPPORT SOFTWARE DISCREPANCY REPORT
STAR	SPACE TRANSPORTATION AUTOMATED RECONFIGURATION
STS	SPACE TRANSPORTATION SYSTEM
STSOC	SPACE TRANSPORTATION SYSTEM OPERATIONS CONTRACT
SW OR S/W	SOFTWARE
SYNVAT	SYSTEM NAME VALIDATION TABLES FOR SMDB
T & O	TEST & OPERATIONS
TCT	TEST COORDINATION TEAM
TR	TRANSMITTAL RELEASE
UAT	USER ACCEPTANCE TEST

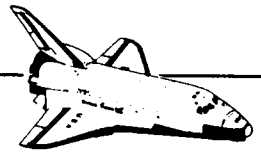
ACRONYMS

UPF	UNIVERSAL PATCH FORMAT
VCS	VEHICLE/CARGO SYSTEMS
VLS	VANDENBERG LAUNCH SITE



APPENDIX D

EXTERNAL EVALUATIONS OF IBM PROCESS



EXTERNAL EVALUATIONS OF IBM PROCESS

- **NASA EXCELLENCE AWARD FOR QUALITY AND PRODUCTIVITY RECIPIENT**
  1986
  IBM Federal Systems Division
  Houston, Texas

- **"To summarize then, the computer software checking system and attitude is of highest quality."**

  Dr. Richard Feynman
  Report of the Presidential Commission on the Space Shuttle Challenger Accident